OKLAHOMA COMPREHENSIVE WATER PLAN

OKLAHOMA WATER RESOURCES BOARD

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OKLAHOMA WATER RESOURCES BOARD

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FOREWORD

Just as an infinite number of possibilities exist for the utilization of water, so are there virtually countless approaches to water resources planning unless general guidance is outlined in advance. The democratic process charges the public with the ultimate responsibility for establishing these policy guidelines, which in turn are translated into specific objectives, thus giving the planning process the direction and momentum necessary to resolve identified problems.

To accomplish selected goals, rules are typically delineated through a series of legislative or administrative policy decisions. Such basic public policies are already set forth in some detail in existing law, primarily having come about in response to previously identified needs. However, planning for the future requires anticipating future problems, while at the same time realizing that problems can occur in the present. Recognition and resolution of major policy issues at the onset of detailed planning allows the planning process to concentrate on the preparation of alternatives which satisfy the goals and objectives in an acceptable fashion.

The Oklahoma Comprehensive Water Plan is designed to accomplish the water-related goals of the State of Oklahoma by setting forth for consideration by the Governor, the Legislature and the people of Oklahoma a strategy for the orderly control, protection, conservation, development and utilization of the state's water resources.

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OKLAHOMA WATER RESOURCES BOARD

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The Honorable George Nigh
Governor of Oklahoma

Members of the Legislature
State of Oklahoma

Citizens of Oklahoma

It is with pleasure that the Oklahoma Water Resources Board submits for your consideration the Oklahoma Comprehensive Water Plan, an orderly, long-range strategy for managing the state's water resources.

Today Oklahoma is faced with the immense task of making critical decisions regarding the wisest use of its most precious natural resource, water. The Board, recognizing the importance of water to our state now and in the future, urges all governmental agencies to consider the construction of additional dams and lakes for the purposes of water storage, flood protection and hydroelectric power generation wherever feasible and practical.

The Board, also cognizant of its responsibility to the environment, urges the solemn stewardship of the state's water resources and the enhancement of the total environment for the benefit and enjoyment of future generations.

The Board concurs with the concern of many Oklahomans that eastern Oklahoma be assured an adequate water supply for industry, agriculture and human consumption, not only for the present, but also for the near and distant future. Such concerns played a pivotal role in the Plan's formulation.

In discharging its responsibility to plan for the development and protection of the state's waters, the Oklahoma Water Resources Board adopted the Oklahoma Comprehensive Water Plan on January 8, 1980. The Board urges the adoption of the Plan and implementation of the recommendations therein as a means of fulfilling all of Oklahoma's present and future water requirements through the year 2040.

GERALDINE BORELLI, Chairman

EARL WALKER, Vice-Chairman

L.L. MALES, Secretary

JEWEL CALLAHAM, Member

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CHAPTER I
DEVELOPMENT OF THE OKLAHOMA COMPREHENSIVE WATER PLAN

PROBLEM AND PROPOSED SOLUTION

Oklahoma has prospered to a remarkable degree in the years since statehood, but the future is clouded by the unwelcome prospect of depletion of the state's natural resources. The need for responsible management of water, the most precious of these natural resources, grows more urgent every day as the state's expanding population places ever greater demands on limited available supplies.

Oklahoma has plenty of water within the state's boundaries to meet all future requirements, but such water is unevenly distributed. Eastern Oklahoma boasts an abundance of stream and ground water resources and rainfall, while western Oklahoma is threatened by droughts and frequently suffers severe water shortages. All areas of the state have at some time been subject to spot shortages caused by water quantity and/or quality problems.

Unless a viable plan for the management of her waters is implemented soon, Oklahoma's vibrant agricultural economy is expected to suffer damaging setbacks and the state's bright potential for further industrial development dim.

The Oklahoma Comprehensive Water Plan is intended to serve as a planning tool for formulation of policy guidelines for managing and developing Oklahoma's water resources. It is believed flexible enough to meet this end, yet rigid enough to provide a solution in itself. In whatever way it is used, immediate steps must be taken to ensure that Oklahoma continues to prosper and grow, and that all her citizens have good quality water in the quantities they need — for today and tomorrow.

AUTHORIZATION AND HISTORY

In 1957 the Oklahoma Legislature created the Oklahoma Water Resources Board, a water authority separate and distinct from precedent agencies, and awarded the Board general statutory authority to begin long-range water resource planning. Title 82 O.S. Supp. 1957, Section 1072(d) directed the Board "...to develop statewide and local plans to assure the best and most effective use and control of water to meet both the current and long-range needs of the people of Oklahoma, and to cooperate in such planning with any public or private agency, entity or person interested in water, and is directed to prepare such plans for consideration and approval by the Legislature."

Although the Oklahoma Water Resources Board had early authority to prepare such plans, limited staff and appropriations impeded this task until 1965, when Congress passed the Water Resources Planning Act (PL 89-80: 70 Stat. 244), which provided grants to states for the specific purpose of preparing state water plans. Pursuant to this act, the Oklahoma Water Resources Board prepared 11 reports which comprise the foundation of the Oklahoma Comprehensive Water Plan. These reports, the "Appraisal of the Water and Related Land Resources of Oklahoma," contained extensive assessments of the hydrologic, economic, geologic and social characteristics of each of the planning regions. Local water problems were identified, and potential water development projects to meet future water needs were outlined.

Upon completion of the regional appraisals, further planning was initiated to compile those reports into a truly statewide plan. In 1974 Senate Bill 510 gave specific statutory authority to the Oklahoma Water Resources Board "to prepare a comprehensive state water plan...including feasibility and cost studies on designated projects within the plan and on the plan itself, for submission to the Legislature...

"Said plan (for 33 southern counties) shall include findings and conclusions for an investigation to determine the economics and engineering feasibility for the development of the land, water and related resources of all proposed projects...(and) shall be of sufficient detail to serve as a basic document for securing legislative authorization. For the balance of the state, the plan shall include office studies of existing data and sufficient reconnaissance field surveys, to indicate whether further detailed investigations are justified, and if so, the scope of such investigations."

Phase I of the Oklahoma Comprehensive Water Plan was developed to meet the projected water needs of southern Oklahoma through the year 2030. It emphasized Oklahoma's southern 33 counties because of the immediate water needs of central Oklahoma and the wealth of information available for the Red River Basin. Phase I featured an interconnected system designed to convey 1.3 million acre-feet of surplus water from southeastern Oklahoma to water-deficient central and southwestern areas of the state. It proposed a network of canals, pipelines, conduits and pumping plants for the conveyance of 487,000 acre-feet of water per year to central Oklahoma for municipal and industrial purposes, and 821,000 acre-feet per year to southwestern Oklahoma, primarily for irrigation.

Phase I of the Oklahoma Comprehensive Water Plan was submitted to the Legislature in 1975, and the Board received further funding to prepare a similar plan for the northern 44 counties through the year 2040. Using legislative appropriations of approximately $100,000 per year, the Board, with assistance from federal, local and other state agencies, continued development of a state water plan.

In September 1977, the Oklahoma Water Resources Board published an Interim Report on the Plan providing preliminary information on the northern 44 counties and evaluating potential funding mechanisms for implementing a state water plan.

During the next two years, the Board's Planning Division worked closely with federal planners to complete hydrologic, economic, engineering and environmental studies necessary to produce a truly comprehensive statewide plan.

Since the authorizing legislation required feasibility and cost studies on projects within the Plan, projects and facilities included in the Regional Plans of Development and those in the conveyance system fulfill this mandate. It should be emphasized that the Oklahoma Comprehensive Water Plan does not advocate redistribution of surplus water to water-deficient areas until and unless additional studies demonstrate the feasibility of such redistribution to the satisfaction of the Governor, the Legislature and the citizens of Oklahoma.

PARTICIPATION

Preparation of a plan as immense in scope as the Oklahoma Comprehensive Water Plan required the expertise of individuals of diverse academic disciplines and the efforts of those at all levels of government. In the initial phase of development, state agencies including the Employment Security Commission, Wildlife Conservation Department, Department of Agriculture as well as the substate planning districts provided data helpful in assessing current water supplies and projecting future water requirements.

As the Plan evolved, the Oklahoma Water Resources Board, along with several federal agencies authorized and funded by Congressional action, became the principal participants in the Oklahoma Comprehensive Water Plan Planning Committee.

The U.S. Army Corps of Engineers has been involved in major water projects in Oklahoma for over 20 years, but the Water Resources Development Act of 1974 first authorized the Corps of Engineers to cooperate with the states in the preparation of plans for the development, utilization and conservation of water and related resources of drainage basins within each state. The Act authorized annual appropriations up to $2 million, and limited funding to $200,000 per state per year.

Among recent water resource planning activities of the Corps are the Central Oklahoma Project (COP) and the Tulsa Urban Study, two investigations significant in the development of the Plan. Planning efforts on the Central Oklahoma Project were initiated over 20 years ago to develop plans to meet the growing municipal and industrial needs of the Oklahoma City metropolitan area. One COP alternative considered was the use of a pipeline to bring surplus water from southeastern Oklahoma to central Oklahoma, a modification of which is included in the Oklahoma Comprehensive Water Plan.

The Tulsa Urban Study is a comprehensive assessment of numerous water resource problems facing Tulsa and the surrounding area. Although vast amounts of stream water are available, much of it is allocated to hydropower generation, and poor quality renders other waters unacceptable for municipal and industrial use. Preliminary information from the study, which is scheduled for completion in 1981, has been incorporated in this Plan. Alternative plans are presently being investigated for meeting regional needs for flood control and floodplain management, recreation, fish and wildlife conservation, navigation, bank stabilization and water supply, with the latter being of particular importance to the Oklahoma Comprehensive Water Plan.

The Bureau of Reclamation participated in the Plan under the general authority of the Federal Reclamation Laws with funds appropriated pursuant to special write-in requests from the Oklahoma Congressional delegation.

In 1966 the Bureau published a reconnaissance appraisal of Oklahoma's water needs entitled, "Water, the Key to Oklahoma's Future." This report presented 100-year water demand projections for Oklahoma, and proposed an extensive water distribution system to carry surplus water from eastern Oklahoma to central and western areas of the state. Major elements of this report were utilized in the present Plan.

The United States Department of Agriculture participated in the Plan's formulation under the authority of Public Law 83-566, as amended. The United States Senate, in a report prepared by the Committee on Appropriations regarding USDA's Environmental and Consumer Protection Bill, directed the Soil Conservation Service to cooperate with the Oklahoma Water Resources Board in developing a comprehensive state water plan to the extent allowed by available funds.

The Soil Conservation Service has funded continuing programs of soil and water conservation throughout the state, with SCS multipurpose structures having long provided protection from floods as well as affording municipal, industrial, irrigation and recreation water supplies in Oklahoma. Optimum utilization of such multipurpose structures is an integral component of the Plan.

The United States Geological Survey, principally a data-gathering agency, also has long provided support to the state with its stream and ground water data-gathering and analysis efforts. Its participation in the planning effort was provided by annual matching fund cooperative agreements with the Board.

All water-related planning studies by federal agencies must include an analysis of a proposed project's environmental impacts. Such analysis includes an assessment of potential adverse effects on critical habitats of fish and wildlife, as well as the project's environmental enhancement features. The United States Fish and Wildlife Service made valuable contributions in evaluating potential environmental impacts of the projects proposed in the Oklahoma Comprehensive Water Plan.

Local participation was achieved primarily through the 11 substate planning districts which assisted in developing projections of local population growth and future water requirements. Meetings were held throughout the state in the early stages of the Plan's development to solicit input for use in the formulation of the Plan. Later meetings focused on the eastern Oklahoma substate planning districts in order to ensure area of origin water needs were adequately provided for.

The Oklahoma Water Resources Board also received input from the Economic Resources Development Association (ERDA), a 24-county organization formed to promote the development of economic, social and industrial potential in eastern Oklahoma. All of ERDA's comments were considered, and where appropriate, incorporated in the Plan.

Many other local, state, regional and federal agencies, boards and commissions provided information in development of the Plan, and still more organizations have an interest or responsibility in water resources or related programs. Appendix C, Figures 6-9, lists those agencies and organizations, defines their functions and summarizes their water-related responsibilities.

GOALS AND OBJECTIVES

Most states have two major goals regarding water resources development; one being the promotion of economic development, and the other, the preservation and enhancement of environmental resources. Although diverse in nature, both goals can be achieved through proper planning. The Oklahoma Water Resources Board has carefully weighed both goals in preparing this Plan, seeking to achieve optimum social and economic growth while at the same time minimizing adverse environmental influences.

The alignment of goals and objectives with established policy guidelines is particularly important in water resources management and development. These goals must be considered both individually and as they may relate to each other for Oklahoma's water resources to be utilized to their maximum potential and to the benefit of all Oklahomans.

From inception through completion, the following goals (which are not listed in order of importance) shaped the Oklahoma Comprehensive Water Plan:

(1) Promotion of economic opportunity and development;
(2) Preservation and enhancement of the environment;
(3) Protection of lives and property from floods;
(4) Expansion of agricultural production and agribusiness activity;
(5) Development of recreational potential;
(6) Maintenance and improvement of water quality;
(7) Encouragement of conservation;
(8) Beneficial use of excess and surplus water; and
(9) Encouragement of and provision for public participation in water resource planning.

POLICIES AND PLANNING GUIDELINES

The Plan to be a Flexible Guide

In order for planning to serve its intended purpose effectively, it must be a dynamic process, reflecting a multitude of economic and social conditions. This characteristic is vitally important to water resource planning, where water demands correlate to residential, commercial and industrial growth, which in turn determine a community's overall economic and social appeal. A plan intended to meet future water needs cannot be "cast in concrete," but rather must remain flexible enough to accommodate events which could cause demands or supplies to vary from those projected.

The Oklahoma Comprehensive Water Plan is designed to meet anticipated water demands through the year 2040, which demands were developed utilizing historical economic and population data. It must be acknowledged that when working toward a 50 to 60-year planning horizon projected needs may or may not occur, thus requiring any plan be updated continuously if it is to remain responsive to changing water needs.

The Plan is intended to and is only capable of serving as a strategy for managing Oklahoma's water resources. Alterations in economic conditions, water requirements, federal and state legislation, and the state of the nation and the world will influence the specific provisions of the Plan as it evolves over the years.

Stream Water Development

Oklahoma's policy regarding surface water development is addressed in 82, O.S. Supp 1979, Section 1085.31, which states: "It is hereby declared to be the policy of the State of Oklahoma to encourage and promote the optimum development and utilization of all feasible reservoir sites or areas within this state which may be suitable and usable for the conservation storage of the waters of this state by the construction or enlargement of dams, reservoirs or other structures." and further that: "Water management in Oklahoma requires the storage of water during periods of surplus supply for use during periods of short supply" (and) "...it is imperative that the reservoir sites be developed to the full potential of the site and the net water yield of the drainage area after all present and future needs and beneficial uses of water are satisfied above said site. The conservation of soil and water in Oklahoma requires the continuation of watershed protection and flood prevention programs on an accelerated priority basis with consideration given to future water needs of the area."

Reservoirs are constructed for a variety of purposes with large federal reservoirs typically being authorized and accruing benefits for six or seven purposes, and smaller structures sometimes being authorized for only a single purpose.

The purposes for which a reservoir is constructed largely depend on the needs of the area in which it is to be located. In many cases, an area will experience not a single water-related problem, but several, so most reservoirs of recent construction are authorized to fulfill as many purposes as are engineeringly and economically feasible. Certain purposes with nonvendible benefits, such as flood control, fish and wildlife enhancement, recreation and water quality control, are regarded as beneficial to the national interest, and thus are authorized as purposes complementary to revenue-producing purposes. Numerous existing single-purpose structures have a potential for expansion and modification to accommodate additional purposes in order that their beneficial uses can be maximized.

It makes sound economic and engineering sense to design and construct a reservoir to a dam site's maximum potential capacity, which is normally determined by the stream's drainage area. In these times of escalating prices of land and the increasing scarcity of suitable dam sites, reservoirs must be planned for eventual development to their maximum capacity. When it is not economical to initially build facilities to optimum limits, development should be planned to accommodate subsequent enlargement.

In accordance with existing Oklahoma law, the Plan assumes development to maximum capacity of all of western Oklahoma's existing and potential reservoirs prior to the importation of water from another area.

The necessity of utilizing storage reservoirs is made clear by analyses of historical streamflow records. Such records indicate that there are periods when stream water of adequate quality is not available in most of Oklahoma's streams on a dependable basis. (Dependable basis for municipal water supply is defined as water available 98 percent of the time.) Therefore, storage must be provided to capture water when it is available for utilization when it is not. Thus, direct diversion from streams is not a viable alternative and was not included in either the regional plans or the statewide plan unless dependable storage in upstream reservoirs was provided for.

Area of Origin Protection and Excess and Surplus Water

The policies of the state regarding area of origin protection and utilization of surplus water were major considerations in the development of the Oklahoma Comprehensive Water Plan. The Plan presupposes that no transfer of water from any area will be considered unless and until all the reasonably foreseeable future water needs of such areas are assured.

Area of origin protection is provided twice in the Oklahoma Statutes. Title 82, O.S. Supp. 1972, Section 105.12 reads in pertinent part: "In the granting of water rights for the transportation of water for use outside the stream system wherein water originates, applicants within such stream system shall have a right to all of the water required to adequately supply the beneficial needs of the water users therein. The Board shall review the needs within such area of origin every five (5) years." Also, 82 O.S., Supp. 1974, Section 1086.1 states in part that, "Only excess and surplus water should be utilized outside of the areas of origin and citizens within the areas of origin have a prior right to water originating therein to the extent that it may be required for beneficial use therein." These sections make it abundantly clear that it is the mandatory duty of the Board to provide for the needs of an area of origin first, and to review such needs on at least a 5-year basis It is thus apparent that any future growth in the water requirements of eastern Oklahoma is specifically provided for and protected by existing law

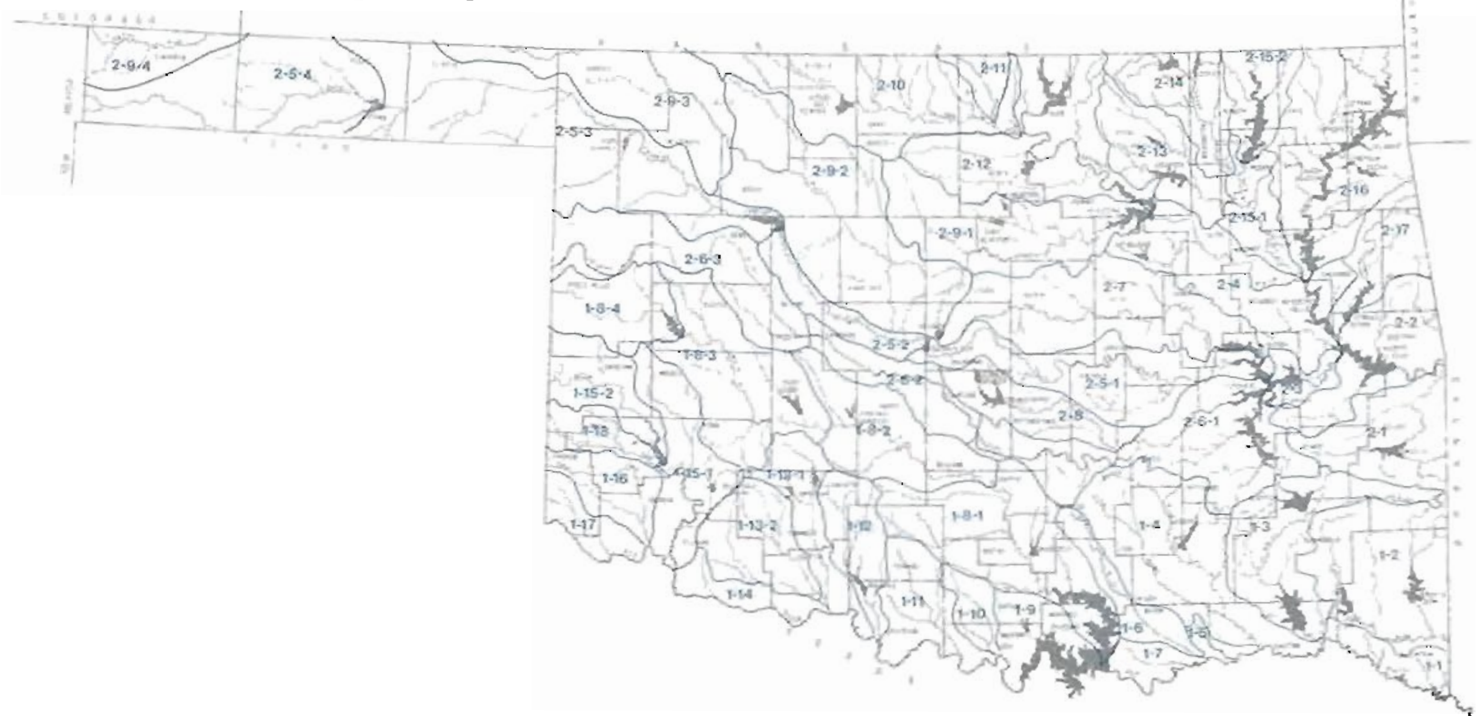
Defining the terms "excess or surplus water" and "area of origin" has been a difficult and controversial issue in Oklahoma. Numerous definitions have been proposed, not only by the Board, but in provisions of various bills which were considered by the 36th and 37th Oklahoma Legislatures. The Oklahoma Water Resources Board believes the definitions and explanations presented below, when viewed in the context of existing legislation, adequately insure that the future water needs of areas of origin will be satisfied prior to any diversion of water for use outside such areas.

Excess or surplus water is defined in part in the Oklahoma Water Resources Board's "Rules, Regulations and Modes of Procedure, 1979 Revision," as follows: "'Excess or surplus water' shall mean that amount of water which is greater than the present or reasonably foreseeable future water requirements needed to satisfy all beneficial uses within an area of origin."

The term "reasonably foreseeable" in this definition has, for purposes of the Oklahoma Comprehensive Water Plan, been considered to be 50 years. The 50-year period was chosen not only because it represents the planning horizon used in the development of the Oklahoma Comprehensive Water Plan, but also because it is consistent with the present state of the art in population and water requirement forecasting, i.e., it marks the outer limits of reliable forecasting capabilities.

In regard to the term "area of origin", the Oklahoma Statutes provide as follows: "The Oklahoma Water Resources Board shall, from time to time as may be necessary for the economical and satisfactory apportionment of the water, divide the state in conformity with the drainage areas, into water districts to be designated by name and to comprise, as far as possible, one or more distinct stream systems in each district. The districts may be changed from time to time as may in its opinion by necessary for the economical and satisfactory apportionment of the water." (82 O.S. Supp. 1972, Section 1085.3). Under the provisions of this statute the Oklahoma Water Resources Board in 1963 divided the state's two major river basins, the Arkansas and Red River Basins, into 35 subdivisions or stream systems. The original 35 stream systems have recently been expanded to 49 as shown in Figure 1, with seven of the larger original stream systems being subdivided into 14 smaller units in order to provide better regulation and management of the state's stream water resources. These stream sytems are the basic hydrological units which

FIGURE 1 OKLAHOMA WATER RESOURCES BOARD STREAM SYSTEMS



RED RIVER AND TRIBUTARIES

Stream System	
1-1	Main stem from Arkansas state line to mouth of Kiamichi River
1-2	Little River
1-3	Kiamichi River
1-4	Muddy Boggy River
1-5	Main stem from mouth of Muddy Boggy to mouth of Blue River
1-6	Blue River
1-7	Main stem from mouth of Blue River to mouth of Washita River
1-8-1	Washita River from the confluence with the Red River to USGS Gage Number 07328500 just west of Pauls Valley
1-8-2	Washita River from the USGS Gage Number 07328500 just west of Pauls Valley to USGS Gage Number 07326500 near Anadarko.
1-8-3	Washita River from the USGS Gage Number 07326500 near Anadarko to Foss Dam
1-8-4	Washita River from Foss Dam to Texas state line
1-9	Main stem from mouth of Washita River to mouth of Walnut Bayou
1-10	Walnut Bayou
1-11	Mud Creek
1-12	Beaver Creek
1-13-1	Cache Creek and Red River between the mouths of Beaver and Cache Creeks
1-13-2	Deep Red Run and West Cache Creek to the confluence with Cache Creek
1-14	Main stem from Cache Creek to North Fork Red River
1-15-1	North Fork Red River from the confluence with the Red River to Altus Dam near Lugert
1-15-2	North Fork Red River from Altus Dam near Lugert to the Texas state line
1-16	Salt Fork Red River
1-17	Prairie Dog Town Fork Red River
1-18	Elm Fork Red River

ARKANSAS RIVER AND TRIBUTARIES

Stream System	
2-1	Poteau River
2-2	Main stem from Arkansas state line to mouth of Canadian River
2-3	Canadian River from mouth, to mouth of North Canadian River
2-4	Main stem from mouth of Canadian River to Keystone Dam
2-5-1	North Canadian River from the confluence with the Canadian River to the diversion dam at Lake Overholser
2-5-2	North Canadian River from the diversion dam at Lake Overholser to Canton Dam
2-5-3	North Canadian River from Canton Dam to Optima Dam
2-5-4	North Canadian River from Optima Dam to the New Mexico state line
2-6-1	Canadian River from the mouth of the North Canadian River to the mouth of Walnut Creek near Purcell
2-6-2	Canadian River from the mouth of Walnut Creek near Purcell to the USGS Gage Number 07228500 near Bridgeport
2-6-3	Canadian River from the USGS Gage Number 07228500 near Bridgeport to the Texas state line
2-7	Deep Fork River
2-8	Little River
2-9-1	Cimarron River from its mouth to the USGS Gage Number 07160000 near Guthrie
2-9-2	Cimarron River from the USGS Gage Number 07160000 near Guthrie to the USGS Gage Number 07158000 near Wayno
2-9-3	Cimarron River from the USGS Gage Number 07158000 near Waynoka to the Kansas state line
2-9-4	Cimarron River from the Colorado state line to the New Mexico state line
2-10	Salt Fork Arkansas River
2-11	Chikaskia River
2-12	Main stem from Keystone Dam to Kansas state line
2-13	Bird Creek
2-14	Caney River
2-15-1	Verdigris River from mouth to Oologah Dam
2-15-2	Verdigris River from Oologah Dam to the Kansas state line
2-16	Grand (Neosho) River
2-17	Illinois River

the Board utilizes in managing and accounting for the stream water resources of the state. They are utilized in reviewing the needs of an area of origin as required under 82 O.S. Supp. 1972, Section 105.12 quoted previously.

In view of "area of origin" being used interchangeably with "stream system" in Section 105.12 and the fact that the Board has established and is using 49 designated stream systems in administering the stream water laws of the state, it is clear that the designated stream systems are the statutorily referenced "areas of origin". As an additional assurance to eastern Oklahoma, various mechanisms have been proposed to provide compensation to areas of origin. Of these, payment in lieu of taxes to local governments appears to be the most appropriate, with existing statutes already providing for such compensation. Title 82 O.S. Supp. 1974, Section 1086.1 further states in part that: "In such cases where storage in the area of origin may be permitted, the purchasing entities shall pay to the county of origin, in lieu of ad valorem taxes and as part of the total cost of the purchase of the water, an amount computed by averaging the tax on land similar to the land taken off the tax rolls as a result of the construction of such storage facilities within the county of origin." This law is quite similar to existing federal "payments in lieu of taxes" provided by Public Law 94-565 which requires the Bureau of Land Management of the Department of Interior to make payments over a 5-year period to local units of government (counties) to help alleviate the financial burdens created by federal ownership of tax-free lands upon which ad valorem taxes cannot be collected by reason of such ownership. Compensation to the area of origin will be further examined in the Board's continued planning activities to insure that a policy is provided for adequate and equitable protection to the area of origin.

Water Quality

Regarding water quality, 82 O.S. Supp. 1972, Section 926.2 states: "Whereas the pollution of the waters of this state constitutes a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and aquatic life, and impairs domestic, agricultural, industrial, recreational and other legitimate beneficial uses of water..., it is hereby declared to be the public policy of this state to conserve the waters of the state and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the state without first being given the degree of treatment necessary to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement and control of new or existing water pollution; and to cooperate with other agencies of this state, agencies of other states and the federal government in carrying out these objectives."

Pursuant to this declaration, the Oklahoma Water Resources Board promulgates Oklahoma's Water Quality Standards which are the basis upon which all the state's water quality regulation and planning activities are predicated.

As important as assessing the quantity of available water supplies is in the design of a comprehensive water plan, the task of supplying all of the state with water of high quality is just as important. To assure high quality water supplies an intricate balance must be maintained between influences on quality such as runoff, climate, geology, urban and rural development, vegetation and natural and man-made pollution. Waters of poor quality have not been considered in the Plan for use either in areas of origin or for conveyance to water-deficient areas.

The anti-degradation policy included as part of the Oklahoma Water Quality Standards protects all waters from degradation in quality, and declares that existing instream water uses shall be maintained and protected.

The beneficial uses assigned to Oklahoma streams include public and private water supplies, emergency public and private water supplies, fish and wildlife propagation, agriculture (livestock watering and irrigation), hydroelectric power generation, industrial and municipal cooling water, primary body contact recreation, secondary body contact recreation, navigation, aesthetics, smallmouth bass fisheries and trout fisheries. The standards serve as a reference in determining the designated beneficial uses of a specific stream and set numerical and descriptive limits on the waters intended for each beneficial use.

The Clean Water Act (PL 92-500) decrees that "where attainable" all waters in the United States shall be fishable and swimmable by July 1, 1983, and that the discharge of pollutants into the nation's lakes and streams shall cease by 1985. Section 208 of the Act requires that Oklahoma and all the states develop plans to achieve these goals. Accordingly, Oklahoma's 208 Areawide Waste Treatment Management Plan divided the state into 59 segments, whose quality characteristics were discussed in seven basin plans describing man-made pollution problems within each basin by categorizing discharges as point or nonpoint sources.

Point sources are basically of two types, municipal and industrial, with municipal discharges attributed to wastewater treatment plants and industrial discharges to private enterprise. The quantity and nature of point source discharges are regulated through the issuance of wasteload discharge permits and subsequent monitoring to assure compliance with such permits. One of the goals of the 208 Areawide Waste Treatment Management Plan is to assure appropriate wasteload allocations in order to protect the beneficial uses assigned to the state's waters. Reasonable wasteload allocations facilitate the writing of permits that are practical and enforceable.

Nonpoint sources are categorized into rural and urban pollution, with rural pollution caused primarily by agricultural and silvaculture practices. The Oklahoma Water Resources Board's approach to solving nonpoint source rural pollution problems will be to emphasise a nonregulatory program aimed at controlling such pollution.

Urban nonpoint sources are primarily due to stormwater runoff — that water from a recent rainfall which moves over natural or manmade terrain, accumulating pollutants in its course. Urban pollutants include litter, nutrients, pesticides, salts, heavy metals and oil and grease, all of which affect the quality of nearby streams and lakes. Although regulatory measures are not considered necessary at this time, it would appear in the state's best interest for Oklahoma's cities and towns to voluntarily initiate stormwater runoff controls.

Since the 208 Areawide Waste Treatment Management Plan is an ongoing effort, any additional problems identified will be considered in subsequent revisions of the Oklahoma Comprehensive Water Plan.

Scenic Rivers

The Legislature enacted the Scenic Rivers Act (82 O.S. Supp. 1979, Section 1452, et seq.) to preserve and protect the natural aesthetic beauty of designated streams. Sections 1452 and 1453 of the Act contain the following language: "The Oklahoma Legislature finds that some of the free-flowing streams and rivers of Oklahoma possess such unique natural scenic beauty, water conservation, fish, wildlife and outdoor recreational values of present and future benefit to the people of the State that it is the policy of the Legislature to preserve these areas for the benefit of the people of Oklahoma Once an area is designated as a 'scenic river area', it is an expression of legislative intent that the stream or river in the area designated be preserved in its free-flowing condition and that the stream or river shall not be impounded by any large dam or structure except as specifically authorized by the Legislature..."

As important as preserving the natural beauty of Oklahoma's "scenic rivers" is protecting the water quality. Pollution of streams designated as "scenic rivers" is specifically prohibited by the anti-degradation policy included as part of Oklahoma's Water Quality Standards. Such streams are protected by prohibition of any new point source discharge of wastes or an increased load from an existing point source at the time of the standards' adoption.

Each of the state's six streams designated as "scenic rivers" are located in eastern Oklahoma. They are the Illinois and Upper Mountain Fork Rivers and Flint, Barren Fork, Big Lee and Little Lee Creeks. Such designation precludes any federal, state or local governmental agency from constructing a dam on the stream without legislative consent, but local communities can build such reservoirs as may be necessary to supply municipal and domestic needs, as long as the structure will not significantly interfere with the preservation of the stream as a scenic, free-flowing stream.

In recognition of these restrictions on scenic rivers, the Oklahoma Comprehensive Water Plan does not propose to impound water on these streams. However, if a municipality located in the counties or in the immediate vicinity of the scenic river area should become interested in developing a reservoir site on any of the six streams, and appropriate legislative authorization were obtained, the Plan could be modified to incorporate such a source.

Environmental Considerations

The Fish and Wildlife Service of the U.S. Department of the Interior has cooperated with the Oklahoma Water Resources Board in the Plan's development in order to ensure the preservation and enhancement of the state's fish and wildlife resources. Although reservoir and canal construction may in some instances be expected to adversely affect local fish and wildlife, conscientious efforts have been made to minimize these effects through appropriate mitigation procedures. To further minimize these effects, downstream releases to maintain suitable streamflows and provide enhanced habitat are planned for as many reservoirs as feasible.

Broad environmental considerations must be assigned high priority in the development of any major water resource project, especially one of the scope of the Oklahoma Comprehensive Water Plan. To assess the environmental impact of the proposed water conveyance system, the Fish and Wildlife Service cooperated closely with the Planning Committee. Parameters evaluated included loss of scarce habitat, reduction in habitat diversity, loss of wetlands, impact on unique Oklahoma fauna, loss of stream fisheries and effect on existing wildlife areas. Preliminary estimates of mitigation/compensation needs have been developed and are included.

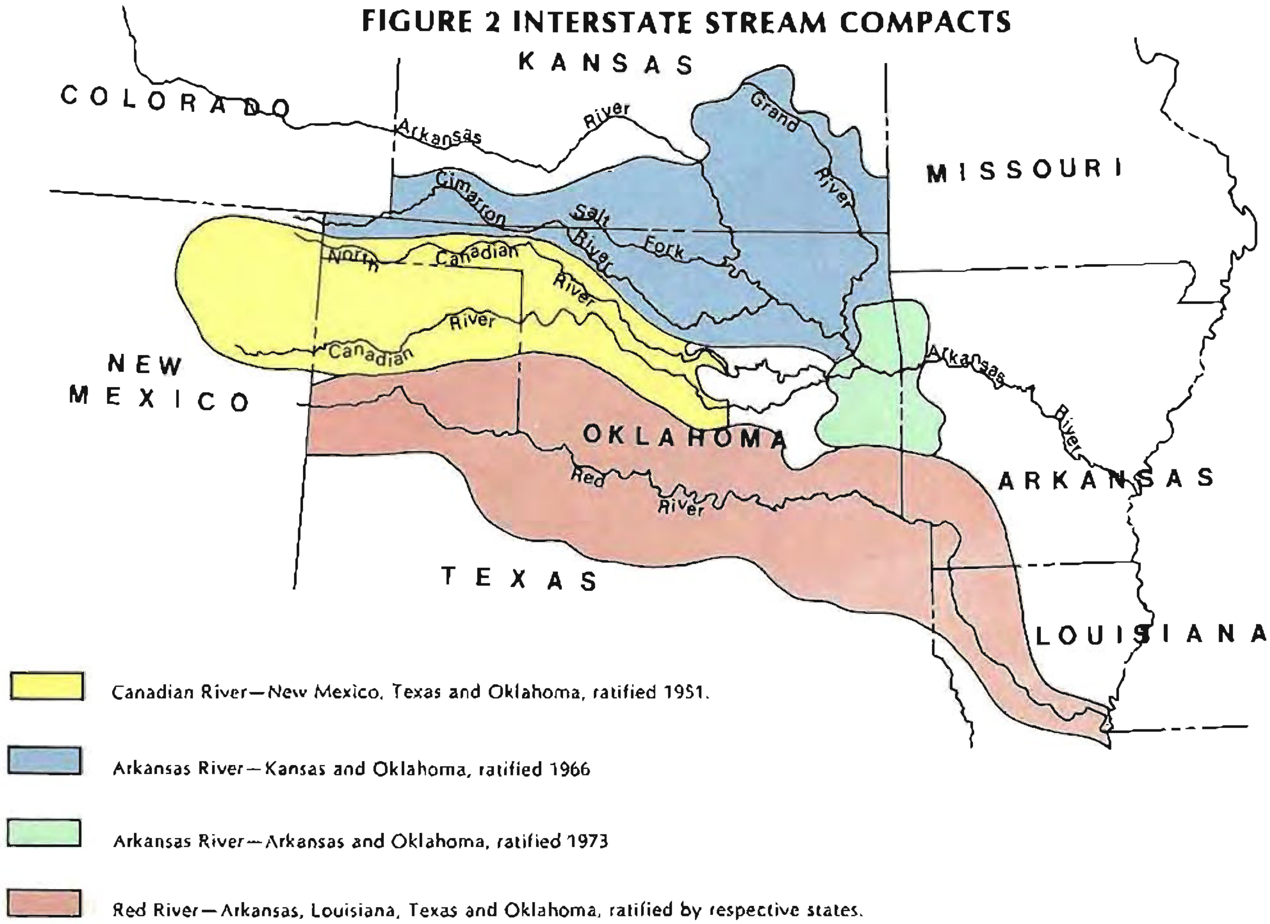
Due to the level of the planning involved in the preparation of the Plan, an environmental impact statement is not required or included. As more detailed planning continues, environmental damages at specific reservoirs and along the proposed distribution canals will be considered more thoroughly so potential adverse effects can be minimized.

Interstate Waters and Stream Compacts

An important consideration in assessing the available water of any area must be those interstate waters apportioned to the signatory states through interstate stream compact agreements. By virtue of four such compacts authorized by Congress, Oklahoma and its neighboring states share in the waters of the Canadian, Arkansas and Red Rivers. See Figure 2.

The Canadian River Compact involving the States of Oklahoma,

FIGURE 2 INTERSTATE STREAM COMPACTS



Data—Oklahoma Water Resources Board
Mapping—Oklahoma Water Resources Board

Texas and New Mexico was ratified by Congress in 1951, and apportions the waters in the Canadian and North Canadian River Basins among the states on the basis of conservation storage limitations.

The Arkansas River and its major tributaries are compacted in two separate agreements. The Arkansas River Compact between Oklahoma and Kansas was ratified by Congress in 1966, and includes the basins of the Cimarron River, the Salt Fork of the Arkansas River, the main stem of the Arkansas from its confluence with the Grand (Neosho) River to the Little Arkansas River in Kansas and the Verdigris and Grand (Neosho) Rivers. The compact divides the water by limiting reservoir conservation storage capacities and sets appropriate limits on new storage for each tributary, as well as on the main stem of the Arkansas.

The Arkansas River Compact between Oklahoma and Arkansas was ratified by Congress in 1973, and apportions waters of the Arkansas River and its tributaries from Fort Smith, Arkansas, to the Arkansas' confluence with the Grand (Neosho) River at Muskogee. This compact allots the water according to streamflow, rather than reservoir storage capacities.

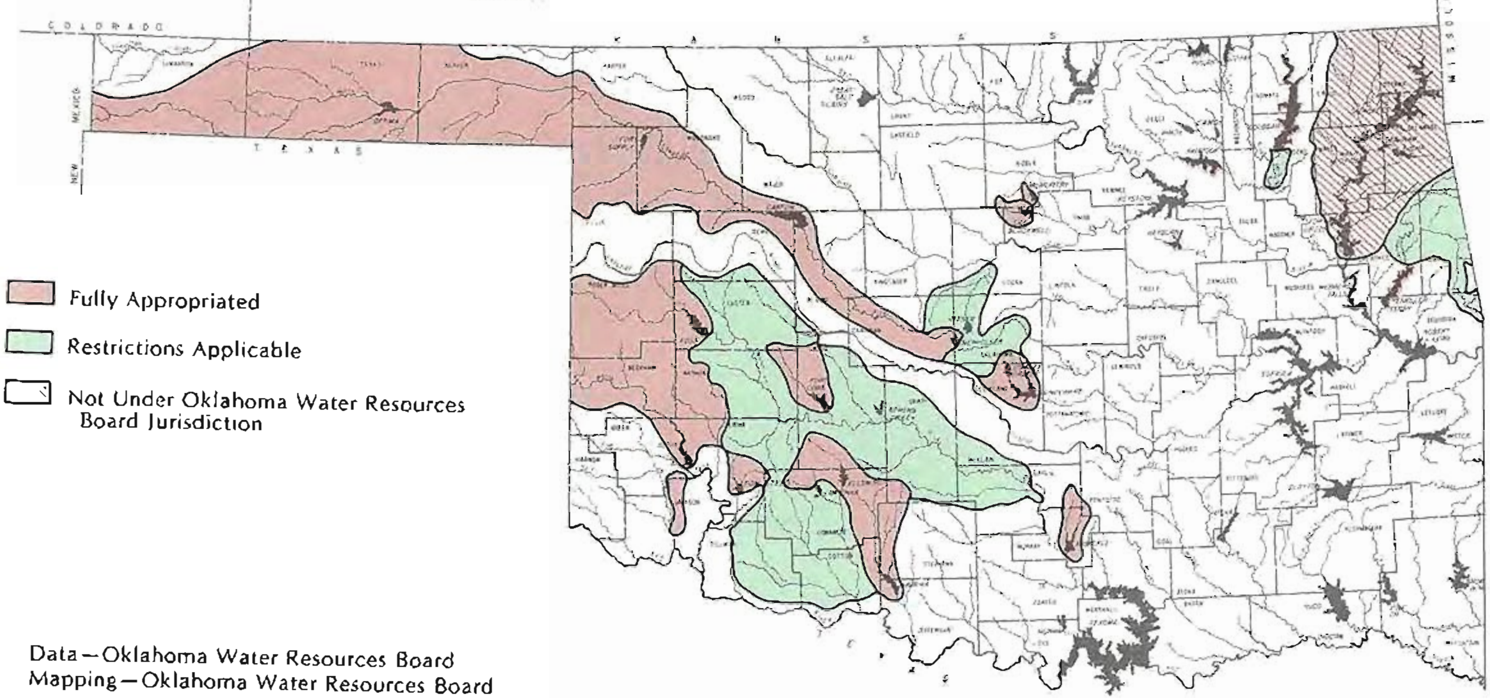
For 23 years compact commissioners representing Oklahoma, Arkansas, Louisiana and Texas worked toward an agreement apportioning the waters of the Red River and its tributaries. Finally, on May 12, 1978, Oklahoma signed its fourth and final interstate stream compact, an agreement dividing the waters of the Red River Basin, primarily according to streamflow allocations. The Red River Compact has been approved by all four states' legislatures and awaits ratification by Congress and approval by the President in order to become final

Grand River Dam Authority

A special consideration in the development of the Oklahoma Comprehensive Water Plan was exemption of the waters of the Grand (Neosho) River Basin from consideration by the Oklahoma Water Resources Board in developing water conveyance plans under the provisions of 82 O.S. Supp 1974, Section 1086.6.

The Grand River Dam Authority was established as a state agency in 1935 with authority to control, store and preserve the river and to use, distribute and sell the waters of the Grand (Neosho) River and its tributaries to the point of confluence with Fort Gibson Dam, but has no jurisdiction below the dam. See Figure 3.

FIGURE 3 STREAM WATER AVAILABILITY



Data—Oklahoma Water Resources Board
Mapping—Oklahoma Water Resources Board

No water from the Grand River can be considered for out-of-basin transfer or for use outside the basin of origin until such water has passed through Fort Gibson Dam. However, for the Plan to be a comprehensive assessment of all the state's water resources, the Oklahoma Water Resources Board has included inbasin studies and water distribution plans for the 24-county area under the jurisdiction of the Grand River Dam Authority.

Ground Water Development

Title 82, O.S. Supp. 1972, Section 1020.2 presents the policy of the state regarding Oklahoma's ground water resources by stating: "It is hereby declared to be the public policy of this State, in the interest of agricultural stability, domestic, municipal, industrial and other beneficial uses, general economy, health and welfare of the State and its citizens to utilize the ground water resources of the State, and for that purpose to provide reasonable regulations for the allocation for reasonable use..."

Although ground water is considered the property of the landowner, the Oklahoma Water Resources Board is authorized to regulate rates of withdrawal in order to conserve and protect limited ground water resources and ensure their equitable allocation.

Interbasin Transfer of Ground Water

While ground water offers an excellent source for certain local municipal, industrial and agricultural water supplies, it is not a practical or viable option as a source for large-scale transfer. Besides being impracticable, its use for transfer would be antithetical to the philosophy of the Oklahoma ground water law, which recognizes ground water as being the private property of the overlying landowner. The maximum annual yield of each ground water basin in the state is allocated to each acre of land overlying the basin. The cost of obtaining ground water rights from the multitude of landowners overlying a basin or basins would be enormous, and a network of feeder lines connecting each well to the primary conveyance system and the easements required for such lines would substantially add to such cost.

Studies to date show that no single ground water basin in the state has sufficient storage capacity, recharge rates and maximum annual yield (aquifer characteristics) to maintain the sustained pumping requirements necessary to produce the quantities of water required to meet the projected future water supply deficits of central and western Oklahoma. A combination of two or more high-yielding basins possibly could provide the quantities necessary, but these basins are situated in central and eastern parts of the state, thus requiring approximately the same amount of conveyance pumping as stream waters from eastern Oklahoma, with additional costs for pumping lifts ranging from a minimum of 200 feet to a maximum of 2,000 feet for bringing the ground water to the surface. Such additional pumping cost would be substantial.

The combination of these negative factors convinced the Planning Committee that transfer of ground water was not a viable option and further study was not warranted.

Sale of Water Across State Lines

The question of the sale and transport of water across state lines has generaged controversy both in

Oklahoma and surrounding states. In this regard, Oklahoma statutes provide specific guidance in two different places. Title 82 O.S. Supp. 1972, Section 1085.2 provides that no contract shall be made conveying the title or use of any waters of the state to any person, firm, corporation or other state or subdivision of government, unless the contract is specifically authorized by the Legislature.

Such contracts are authorized by 11 O.S. 1977, Section 37-127, which provides that an incorporated municipality of an adjoining state may own a reservoir in Oklahoma, albeit only under extremely limited circumstances.

A plain reading of these sections renders the inescapable conclusion that there are substantial limitations and conditions under which water may be used, transported or sold outside Oklahoma.

Conservation

Recognizing the increasing demand on Oklahoma's renewable natural resources, the Oklahoma Legislature emphasized the importance of conservation in 82 O.S. 1971, Section 1501-102: "...it is hereby declared to be the policy of the State of Oklahoma to provide for the conservation of the renewable natural resources of this state, and for the control and prevention of soil erosion, and for the prevention of floodwater and sediment damages, and for furthering the conservation, development, utilization and disposal of water, and thereby to preserve and develop natural resources, control floods, conserve and develop water resources and water quality, prevent impairment of dams and reservoirs, preserve wildlife, preserve natural beauty, promote recreational development, protect the tax base, protect public lands and protect and promote the health, safety and general welfare of the people of this state." To implement this policy the Legislature created conservation districts as a primary local unit of government responsible for the conservation of renewable natural resources.

Although water conservation in agriculture, municipal, industrial and domestic usage allows limited supplies to last longer, it simply delays the need for additional water supplies in water-deficient areas. It does not in itself create any new supply of water. The Plan recognizes the significance of a state conservation program and includes a guide to water conservation in Chapter III.

Special-Purpose Districts

Special-purpose districts — master conservancy, irrigation, weather modification and rural water districts — are local legal entities authorized to distribute, regulate, contract and pay for water used for municipal, industrial and irrigation purposes. These districts often serve the function of supplying water to areas that would otherwise be deprived of adequate supplies.

Since special-purpose districts will aid in distributing the additional water supplied by the conveyance system and in providing repayment through assessment of district participants, their role will assume even greater importance upon implementation of the Plan.

Indian and Federal Reserved Water Rights

The Oklahoma Comprehensive Water Plan was developed with due consideration of federal reserved and Indian water rights.

Generally, Oklahoma acknowledges as a matter of law that a federal reserved water right is established when the Federal Government withdraws its land from the public domain and reserves it for a federal purpose. The key factor in determining the existence of a reserved right is to ascertain whether or not the government intended to reserve then unappropriated and thus available accompanying water at the time the federal enclave was created.

In regard to Indian water rights, the State of Oklahoma recognizes the Winters Doctrine derived from the U.S. Supreme Court ruling in Winters vs. the United States (1908), which doctrine maintains that water rights may be attached to Indian reservations created by lawful means, i.e., treaties, acts of Congress or executive orders. However, it should be noted that no Indian reservations presently exist in Oklahoma, with those previously existing being substantially dissolved by allotment of lands in severalty during the period of time from 1891 through 1906.

The future water needs of Oklahoma's substantial Indian population have been considered within the water requirement projections included in the Oklahoma Comprehensive Water Plan.

Federal Programs

Throughout the development of the Plan, the Oklahoma Water Resources Board has remained cognizant of federal programs underway in the state, and has integrated all appropriate federally authorized projects and study proposals into the total water development program.

Reclamation Law

Due to the magnitude of the Plan, it is almost certain that federal planning and financial assistance will be required in its implementation. Such federal participation will necessitate adherence to certain laws and regulations, including the Reclamation Act of 1902. Certain provisions of this law could potentially hinder water planning efforts in Oklahoma, as well as all western states.

The intent of the Reclamation Act was to encourage and facilitate the development of vast areas of public land in semi-arid regions of the western United States by providing for the development of irrigation water supplies. The original version of the law did not require water users to pay interest on their share of the cost to construct irrigation facilities, nor did it allow a private landowner to obtain water from a Bureau of Reclamation project for use on a plot larger than 160 acres.

Essentially, this rule excludes today's average or large farm owner from participating in an irrigation project constructed by the Bureau of Reclamation. When the law was passed in 1902, farming practices relied exclusively on human and animal power using crude farm implements. The years since have brought revolutions in the farming industry, which require costly and complicated machines for the planting, cultivation and harvesting of agricultural products which cannot be justified by the returns on a small farm.

In 1977 the average Oklahoma farm size was an estimated 428 acres — over three times the average size at the turn of the century. Studies of farm economics set the optimum farm size in most areas at 640 acres or more.

Considering the necessity of heavy capital investment by the farmer and the emphasis on increased food production for a starving world, realistic modification of the "160-Acre Limitation Rule" would appear imperative. Even with the practice of allowing the farmer and his wife to claim 160 acres each, totaling 320 acres per family, the amount remains insufficient to make the operation cost-effective. At the present time, Congress is considering raising the 160-acre limitation.

Proposed National Water Policy

National water policy plays an important role in state water resource management, particularly in areas requiring federal technical assistance and construction priorities. Policy direction is provided through the U.S. Water Resources Council (WRC), an independent administrative agency created in 1965 under Public Law 89-80. In May 1977, President Carter initiated a National Water Policy Study which culminated in the following stated initiatives:

—Improve planning and efficient management of federal water resource programs to prevent waste and to permit necessary water projects which are cost-effective, safe and environmentally sound to move forward expeditiously.

—Prove a new, national emphasis on water conservation.

—Enhance federal-state cooperation and improved state water resource planning.

—Increase attention to environmental quality.

The Water Resources Council was directed to improve the implementation of the Principles and Standards governing the planning of federal water projects by: (1) adding water conservation as a specific component of both the economic and environmental objectives; (2) requiring the explicit formulation and consideration of a primary nonstrucural plan as one alternative whenever structural water projects or programs are planned; (3) preparation of a planning manual designed to institute consistent cost-benefit analyses among federal water agencies; and (4) creation of a project review function within the Council to ensure water projects have been planned in accordance with the Principles and Standards. These provisions would apply to all federal projects (and separable project features) not yet authorized.

Federal agencies with programs affecting water supply or consumption were directed to encourage water conservation by:

—developing water conservation programs in federal facilities;

—requiring conservation measures as a condition for certain water supply and wastewater treatment grant and loan programs;

—providing technical assistance to the public, and

—requiring conservation as a condition of contracts for storage or delivery of municipal and industrial water supplies from federal projects.

The Bureau of Reclamation was specifically directed to renegotiate new and renewable irrigation repayment and water service contracts every five years to replace previous 40-year contracts; add provisions to recover operation and maintenance costs; and calculate and implement more precisely the "ability to pay" provision.

All federal agencies were requested to adhere vigorously to appropriate environmental statutes in water resource development and to arrange funding for environmental mitigation. Certain agencies were directed to acquire flood-prone property to reduce flood damages and discourage utilization of floodplain areas.

The Soil Conservation Service was directed to take more effective conservation measures by encouraging accelerated land treatment practices prior to funding of structural facilities on watershed projects and establishing periodic post-project monitoring to ensure implementation of land treatment and operation and maintenance activities specified in the work plan.

Initiatives directly impacting on the states include new cost-sharing arrangements, the option to charge higher prices for municipal and industrial water (provided that revenues in excess of federal costs be returned to municipalities for use in conservation or water supply systems), increased federal funding for water resource planning and new funding for water conservation programs.

Since unveiling of the new national water policy, many state water officials have expressed concern regarding the new cost-sharing agreements, the federal agencies have grown apprehensive of the revised Principles and Standards and Congress has not been supportive of enhanced funding levels in an era of spiraling inflation rates.

Oklahoma's reaction has also been apprehensive, principally since the state does not possess a financing program capable of funding major water resource projects and thus the proposed cost-sharing arrangements could restrict the state's future water resource development. Senate Bill 215 (82 O.S. Supp. 1979, Section 1085.31 et seq.) passed by the First Session of the 37th Legislature does provide funding for small water-related projects, but its loan limitation of $1.5 million per project precludes the financing of major reservoirs. Texas, Arkansas, California and other states which already possess an adequate funding mechanism will have a distinct advantage over Oklahoma, since they will be immediately able to provide any required state funding share.

Concerns have also been expressed that the revised Principles and Standards could adversely affect all western states producing irrigated agricultural crops by including new methods of determining project benefits which would deflate benefits from other water supply purposes, thus severely retarding water resource development in the west.

In spite of these concerns, water conservation in the context of wisely managing and using the state's limited water resources is clearly necessary, and thus the national emphasis on water conservation is welcomed in Oklahoma. Additional funding through the proposed technical assistance programs could expedite the preparation of state conservation programs and allow further study and possible implementation of the water conservation recommendations included in the Oklahoma Comprehensive Water Plan.

ALTERNATIVES TO WATER TRANSFER

In the development of the Oklahoma Comprehensive Water Plan, various nontransfer alternatives possibly capable of meeting Oklahoma's projected water demands were analyzed. These were of both a structural and nonstructural nature and included weather modification, artificial recharge, desalination, wastewater reuse, chloride control and water management. In addition, a no-action scenario was evaluated to project the consequences of present trends continuing into the future without material alteration.

Conclusions from such analyses strongly indicate that, while these alternatives may individually and/or collectively provide additional water, the amount is insignificant compared to Oklahoma's total future water needs. Therefore, nontransfer alternatives were considered only as supplemental sources of water, not capable of wholly fulfilling the state's long-range water requirements. Nonetheless, these alternatives should receive continued emphasis on a local basis as ongoing planning efforts continue.

Each of the nontransfer alternatives is influenced by certain constraints imposed by technology, economics and institutional and political limitations. These constraints make extremely difficult a precise quantification of the water made available from such methods. However, a brief assessment of some nontransfer alternatives, as well as the no-action scenario, follows and they should be further considered in future planning efforts.

Weather Modification

Recurrent droughts in Oklahoma have sustained interest in weather modification, but real technological advances in the field have only recently been recorded. Although weather modification appears to be a promising means of supplementing water supplies, potential adverse effects and legal problems have caused concern and threaten to hinder the effectiveness of future efforts. Opponents have attributed tornados, local flooding and hail to weather management activities and charge that storms intensified in one area may rob another area of rain. However, due to the difficulty in establishing substantive evidence between weather modification efforts and alleged injuries, court decisions have most often favored proponents of the practice.

The most common form of weather modification is cloud seeding — injecting silver iodide particiles into rain clouds from ground-based dispensers or aircraft. Although opinions vary widely, the potential for increasing annual precipitation has been estimated at 10 to 30 percent. However, for any program of weather management to be a significant factor in water development, it would have to embrace several counties, if not the entire state, and include adequate guidelines and direction from professional meteorologists and hydrologists.

Interest in producing or supplementing rainfall by artificial means caused the State Legislature to pass the Oklahoma Weather Modification Act (2 O.S. Supp. 1972, Section 1401 et seq.). The Act provided for the encouragement and regulation of weather modification activities, and as amended in 1973, assigned the responsibility of its admininstration to the Oklahoma Water Resources Board. The Act also authorized local entities to hold elections and assess themselves in order to contract for weather modification services.

The Oklahoma Water Resources Board appointed an advisory committee composed of 10 members knowledgeable in the field to advise the Board in matters of policy, administration, research and legislation pertaining to weather modification. The Board regulates operations and exercises its powers to promote continued research and development of the technology.

The Board is sponsoring the preparation of a state weather modification plan which will make recommendations regarding state policy on weather management, determine proper utilization of the technology and address legal implications to ensure minimal adverse effects.

Although weather modification may eventually offer a means of supplementing water supplies, the present state of the art limits the precision of rainmaking efforts, and legal questions concerning use of the technology remain unresolved. At best, weather modification can be relied on to produce only limited quantities of supplemental water, and then only when appropriate weather conditions exist.

Artificial Recharge

Artificial recharge is the process of replenishing a ground water aquifer with fresh water by diverting

Artificial Recharge

Artificial recharge is the process of replenishing a ground water aquifer with fresh water by diverting stream water and/or irrigation runoff into abandoned wells and natural depressions, which then act as recharge sites. Induced recharge reduces the amount of water lost to evaporation and transpiration, as well as decreasing the possibility of encroachment by salt water from beneath an overdrafted aquifer.

The only extensive artificial recharge project in Oklahoma is located in the Dog Creek Shale and Blaine Gypsum Formation in southwestern Oklahoma, where it has proven to be a fairly successful augmentation program. It has enabled the local farmers to sustain irrigation in an area where irrigation water supplies had been threatened by overdevelopment of ground water resources.

Although the Dog Creek project has proven somewhat successful, there have been concerns regarding possible pesticide, herbicide and nitrate contamination from agricultural runoff water being diverted into the formation. Since the Blaine Gypsum is used almost exclusively for irrigation, this problem is not considered critical, however there is a possibility that the contaminated recharged water could infiltrate other local aquifers which provide drinking water supplies. Any further recharge operations in the area should incorporate appropriate water quality monitoring to insure that existing municipal and industrial water sources are not contaminated.

Few other areas in the state are considered geologically suitable for the development of artificial recharge projects. These natural limitations, along with the high costs of pilot projects, test drilling and hydrologic studies which must lay the groundwork, have discouraged further experimentation. The lack of dependable recharge sources, escalating energy costs and sediment problems in recharge water also make it unlikely that artificial recharge will prove a practical solution to water supply problems. At best, the technique can be relied upon to provide a few areas with supplemental water, and then only if the costs can be justified.

Desalination and Chloride Control Projects

Much of Oklahoma's water is unavailable for beneficial use due to its poor quality. High concentrations of minerals, particularly chlorides, are emitted into streams, rendering both the stream and adjacent alluvium and terrace ground water deposits unfit for use. This problem attains critical proportions in water-deficient areas of the state, such as the Southwest and Northwest Planning Regions. In the northwest, streams polluted by chlorides provide the only stream water available, and the area's primary ground water aquifer, the Ogallala, is threatened by depletion. In western Oklahoma large quantities of brackish stream and ground water remain unusable. If such waters could be purified at reasonable cost and minimal adverse environmental impact, significant additional quantites of water would be available for beneficial use.

Two major methods, desalination and chloride control, have been suggested to cope with this salt pollution. Desalination involves purifying heavily salt-polluted water in order that its quality becomes appropriate for beneficial use. Chloride control does not alter the quality of the water at its source, but rather diverts fresh and usable water around identified salt flats and natural brine springs by means of dikes, dams and retention reservoirs, i.e. allowing the better quality water to bypass pollution sources and thus retain its quality.

Research and development activities have brought desalination technology to a point where its importance as a source for municipal and industrial water supply is widely recognized. However, under the present state of the art, the unit cost of storage and desalination is cost-prohibitive to the production of irrigation water.

DESALINATION

The feasibility of desalination in Oklahoma will depend heavily upon the environmental and economic aspects of the Foss Reservoir desalination plant located in Custer County. After completion of Foss Reservoir in 1961, it was discovered that water captured in the lake was of poorer quality than expected. The inferior quality of the water was attributed to an unprecendented depletion of inflow caused by prolonged drought and extensive upstream watershed development. It was also determined that conventional treatment would not produce a water supply of sufficient quality to meet U.S. Public Health Service standards. Studies were conducted to identify alternate water sources and to determine the most feasible method of alleviating the water quality problems. The study recommended construction of a desalination plant as the most practical and economical solution for an area with virtually no other stream water sources and only limited ground water supplies available. A desalination plant at the Foss site was begun in 1972, funded by a grant and loan from the U.S. Department of Housing and Urban Development, and began operation in 1974.

Desalination of brackish water may provide an alternative solution to future water supply problems. However, the high cost of treatment and environmental problems involved with disposal of the highly concentrated brine effluent from the conversion process could preclude desalination as a feasible solution, except in areas without alternative water sources. Ongoing studies by the Oklahoma Water Resources Board concerning the effects of the brine effluent discharged from the Foss Reservoir desalination plant on the quality of the Washita River should be of assistance in ascertaining the magnitude of the problem.

Although the cost of proper disposal may be the determining factor as to whether desalination is feasible or not, satisfactory effluent disposal to prevent stream and ground water pollution is imperative. Disposal methods include evaporation ponds lined to prevent seepage, subsurface injection, use of the effluent for secondary oil recovery, and discharge into streams in compliance with state water quality standards.

Advances in desalination technology should be closely monitored and further studies conducted to determine the feasibility of the process. Financial assistance from federal and state sources could provide incentives, especially in areas experiencing a shortage of good quality water, but an abundance of poor quality water.

CHLORIDE CONTROL

If constructed, the authorized Arkansas-Red River Basin Chloride Control projects would make available for beneficial use large quantities of stream water currently unusable due to natural chloride pollution. However, studies indicate that the chloride control projects cannot be considered an alternative to water transfer, but would reduce the amount required by making higher quality water available in water-deficient areas.

Surplus water from the Arkansas River suitable for municipal, industrial and irrigation uses is presently available only during periods of high stream flow. High flows (flood waters) dilute the excessive chloride concentrations that occur during periods of low flow, thus enabling water of adequate quality to be diverted during such high flow periods.

Alternative transfer systems were formulated for water quality conditions that would exist with operational Arkansas River Basin Chloride Control projects and without such measures.

With the projects operational, the availability of surplus water suitable for municipal, industrial and irrigation uses would be greatly increased. Thus, a given volume of good quality surplus water could be more economically diverted from the Arkansas River, due to more frequent diversions of smaller quantities.

Future planning efforts will address additional water transfer alternatives in the Red River Basin assuming that the chloride control projects are operational. Preliminary studies indicate that water of suitable quality for irrigation purposes in southwestern Oklahoma could be developed from the Red River in south central Oklahoma, thereby significantly reducing the need for water sources in eastern Oklahoma. Such an alternative is briefly discussed in Chapter VI, which describes the southern water conveyance system.

Since the effective solution of salt pollution problems in western Oklahoma could make significant quantities of good quality water available in those areas, desalination and chloride control should be addressed in more detail in future planning efforts.

Conservation

Many water conservation measures are available to prolong the life of limited supplies, including mechanical techniques, water management, wastewater reuse, conjunctive use of stream and ground water, and water pricing practices. The potential of each of these methods is discussed in greater detail in Chapter III, "Water Conservation in Oklahoma."

No Action

One of the options available to the State of Oklahoma is simply to take no action in implementing a comprehensive statewide water plan. Such a scenario assumes current trends will continue in water demand and supply management, i.e., the state will make no new efforts to reduce demands or augment supplies. All water users — domestic, municipal, rural, industrial, agricultural and others — would continue to rely on available local ground and stream water resources, regardless of the quantity and/or quality of those waters.

Adverse consequences of this no-action alternative seem predictable. After developing available local supplies, the larger, more affluent cities would continue to obtain water from other areas of the state, despite the high cost of constructing the necessary independent transfer systems. If urban areas were given priority due to their ability to fund major water projects, and local supplies were to be allocated to them, some towns, smaller cities and rural areas could be deprived of adequate water supplies.

Areas which do not presently have adequate fresh water supplies would be denied growth because they could neither support agricultural development nor attract business and industry. Irrigation farmers in western Oklahoma would be forced to revert to dryland farming as depleting ground water supplies become too costly to use. As a result, per-acre crop yields would decline, requiring an increase in the number of acres planted to maintain current production levels. Increased costs would reduce profit margins, placing many farmers in a tenuous financial position.

Oklahoma is presently experiencing healthy and balanced growth and expansion, but it is obvious from the rate at which water consumption is exceeding supply, that by the turn of the century some areas could decline into an economic recession with profound economic effects on the entire state.

The Statewide Economic Impact Study, discussed more fully in Chapter VIII, is assessing the economic effects on the state "without water conveyance." The study, scheduled for completion in early 1981, will evaluate the impacts of inaction on local, regional and state economies. Preliminary appraisals project severe reprecussions, not only in agriculture, but in all sectors of the state's economy, unless Oklahomans possess the vision to begin providing now for future water supplies.

CONCLUDING NOTE

Oklahoma's history is illuminated by its dramatic record of success in water resource development, even though and perhaps in spite of the fact that the state has thus far lacked a plan to insure the orderly control, protection, conservation, development and utilization of its precious water resources. It would seem unlikely that such a record can continue without adoption of a plan for future growth as growing population and expanding industry press new and greater demands on Oklahoma's dwindling water supplies.

The Oklahoma Comprehensive Water Plan, prepared in cognizance of state and federal policies and guidelines and advancing the goals and objectives set forth herein, fulfills this need for a flexible guide to the development of Oklahoma's water resources on regional and statewide basis. Only with such guidance can the State of Oklahoma attain the bright destiny its history would portend.

CHAPTER II
OKLAHOMA WATER LAW AND ITS ADMINISTRATION

CLASSIFICATION OF WATER

Depending upon the natural state in which it is found, water in Oklahoma has been classified into five basic categories: ground water, diffused surface water, watercourses or definite streams, lakes and atmospheric water. In many instances it may be difficult to ascertain the specific class into which certain water may fall, since one often merges into another.

Ground Water

Oklahoma statutes define "ground water" as water under the surface of the earth regardless of the geologic structure in which it is standing or moving as long as it is outside the cut bank of a definite stream (82 O.S. Supp. 1972, §1020.1A).

Ground or subsurface water is generally recognized as falling into one of two categories: percolating ground water or underground streams. Percolating ground water filtrates or percolates through the soil or interstices of the rock while an underground stream must have a well defined and known channel under the surface of the earth "outside the cut bank of any definite stream".

Diffused Surface Water

The Oklahoma Supreme Court in 1909 (Jefferson v. Hicks, 23 Okl. 684, 102 P. 79) quoted with favor a definition of "surface water" originally given by a Federal Court in 1894 as:

> "...that which is diffused over the ground from falling rains or melting snows, and continues to be such until it reaches some bed or channel in which water is accustomed to flow. Surface water ceases to be such when it enters a watercourse in which it is accustomed to flow, for, having entered the stream, it becomes a part of it, and loses its original character."

In recent times courts and scholars alike have preferred the term "diffused surface water" as a more accurate and descriptive expression since the term "surface water" is somewhat misleading. This is so because all waters appearing on the surface of the earth, whether they are found in definite streams or elsewhere, are technically surface waters.

The Oklahoma Supreme Court has stated that the two terms, "surface water" and "diffused surface water", are synonymous and, further, that:

> "Surface waters are those which, in their natural state, occur on the surface of the earth in places other than definite streams or lakes or ponds. They may originate from any source and may be flowing vagrantly over broad lateral areas or, occasionally for brief periods, in natural depressions. The essential characteristics of such waters are that their short-lived flows are diffused over the ground and are not concentrated or confined in bodies of water conforming to the definition of lakes or ponds." (Oklahoma Water Resources Bd. v. Central Oklahoma Master Conservancy Dist., 464 P. 2d 748, 1969).

"Oklahoma Water Resources Board Rules, Regulations and Modes of Procedure" (1979 Revision) give a simplified definition of "diffused surface water" as:

> "water that occurs, in its natural state, in places on the surface of the ground other than in a definite stream or lake or pond."

Stream Water

The statutes define "definite stream" as:

> "a watercourse in a definite, natural channel, with defined beds and banks, originating from a definite source or sources of supply. The stream may flow intermittently or at irregular intervals if that is characteristic of the sources of supply in the area." (82 O.S. Supp. 1972, §105.1A).

Therefore, it may be said that where the natural conformation of the surrounding country necessarily collects therein so large a body of water, after heavy rains or the melting of large bodies of snow, as to require an outlet to some common reservoir, and where such surface water is regularly discharged through a well-defined channel which the force of the water has made for itself and which is the accustomed channel through which it flows or has ever flowed, it constitutes a defined channel. It is not essential to the existence of a "definite" stream that its source of supply be spring water. It may be surface water collected within a large watershed from rain and melted snow which concentrates and cuts for itself a well-defined channel and regularly discharges through such outlet. Nor is it essential that there be a constant and continuous flow of water. The Oklahoma Supreme Court has said that the determinative question in every case is whether the water precipitated in the form of rain or snow has formed for itself a visible course or channel, and is of sufficient magnitude or volume to show frequent action of running water. (Oklahoma Water Resources Bd. v. Central Oklahoma Master Conservancy Dist., 464 P. 2d 748, 1969).

With regard to natural spring water and its legal classification under Oklahoma law, the Oklahoma Supreme Court in 1977 held that while ground water was admittedly the water source for underground springs which ultimately rise to the surface of the ground, such spring water becomes Oklahoma "stream water" when the spring water forms a definite stream. In interpreting Oklahoma's statutory references and definitions of "ground water" and the waters of a "definite stream", the Court ruled that when a natural spring forms a definite stream, the water in the stream and the spring itself, "from its inception", must be classified as stream water, not as ground water, and must be appropriated as such. In this connection the Court observed that it was immaterial that such spring water may, upon reaching the surface, run across the surface for some distance in a nondefinite or diffused course as long as the spring formed or was the source of a definite stream. (Okla. Water Resources Bd. v. City of Lawton, 580 P.2d 510, 1977).

Lakes

While the terms "lake" and "reservoir" are not statutorily defined, Oklahoma Water Resources Board rules and regulations define "reservoir" as any surface depression which contains or will contain the water impounded by a dam. Generally, the rules of law relating to lakes or reservoirs are analogous to those concerning watercourses. Under the terms of Title 60, §60, as well as at common law, diffused surface waters lose their original character when they reach some well-defined channel and flow with other waters to reach some permanent lake or pond.

Atmospheric Water

Water is constantly being exchanged between the earth and the atmosphere. Water evaporates from the earth, is carried in the air as water vapor, a gas, and as it condenses changes from gas to liquid again and falls as rain.

Weather modification activities in Oklahoma are regulated by the Oklahoma Water Resources Board under the provisions of Title 2 O.S. Supp. 1972, §1401 et seq., as amended.

Other than a suit for damages against an operator for allegedly causing a flood near El Reno with the verdict being for the defendant (Samples v. Irving Krick, Inc. Civ. Nos. 6212, 6223 and 6224, W.D. Okl, 1954), Oklahoma courts have not had occasion to deal with the legal aspects of cloud seeding or rainmaking attempts nor the effects created by such activities.

HISTORY OF WATER LAW ADMINISTRATION IN OKLAHOMA

Following passage of the Homestead Act in 1862, pioneers began moving westward taking up land for agricultural purposes, and the need for irrigation water was recognized.

On May 2, 1890 the Territory of Oklahoma was created out of the western part of what had been known as Indian Territory, with the eastern part of which is now Oklahoma remaining Indian Territory.

In 1902 President Theodore Roosevelt signed into law the Reclamation Act which established a special fund to be used in the examination and survey for, and the construction and maintenance of, irrigation works for storage, diversion, and development of waters for the reclamation of arid and semiarid lands. Oklahoma Territory was specifically mentioned in the Act and the following year investigations were begun to determine how water supplies could best benefit the Territory.

Early Water Laws

The Eighth Legislative Assembly of the Territory of Oklahoma in 1905 enacted water laws outlining the procedure for acquiring water rights, regulating the use of water, and creating the office of the Territorial Engineer, as well as outlining his duties.

The drive for statehood in Oklahoma Territory began early. The Enabling Act was approved June 16, 1906, and provided for admission to the Union of the Territory of Oklahoma and the Indian Territory as the single State of Oklahoma.

The Constitution of Oklahoma, effective November 16, 1907, provided in Article XVI, §3:

> "The Legislature shall have power and shall provide for a system of levees, drains, and ditches and of irrigation in this state when deemed expedient, and provide for a system of taxation on the lands affected or benefited by such levees, drains, and ditches and irrigation, or on crops produced on such land, to discharge such bonded indebtedness or expenses necessarily incurred in the establishment of such improvements; and to provide for compulsory issuance of bonds by the owners or lessees of the lands benefited or affected by such levees, drains, and ditches or irrigation."

The First Session of the Oklahoma Legislature passed House Bill 482 (S.L. 1907-08, Chapter 30). This bill was known as the Oklahoma State Drainage Act, and it authorized county commissioners to form drainage districts to ensure an adequate amount of irrigation water was available for usage. Also, the State Engineer assumed all powers held before Statehood by the Territorial Engineer.

Commissioners of Drainage and Irrigation

House Bill 47 (S.L. 1923-24, Chapter 139) created the Commissioners of Drainage and Irrigation for the State of Oklahoma. The Act called for five commissioners to be appointed by the Governor with the advice and consent of the Senate.

District courts were given the power to establish within their jurisdiction conservancy districts for the purposes of preventing floods, regulating stream channels, providing for irrigation, reclaiming or filling of wetlands, regulating stream flows and diverting water flows. The district judge also appointed three persons in his district to serve as a board of directors for the conservancy district.

Persons, corporations, municipalities or other parties desiring to secure the use of water in a particular district had to make application to the Board of Directors in its district for the right to use that water. Preference for water rights was given to those with the greatest need and the most reasonable use. Boards of Directors also had the power to provide financing for water projects by issuing bonds at a rate not to exceed six percent per annum.

Commission of Drainage, Irrigation and Reclamation

House Bill 47 (S.L. 1925, Chapter 149) created the Commission of Drainage, Irrigation and Reclamation of the State of Oklahoma. This act reduced the number of commissioners from five to three. It also transferred the powers and duties conferred upon the State Engineer and upon the State Highway Engineer, pertaining to waters, drainage, irrigation and water control, to the Commission. The powers of the Commission were broadened to include supervision of lakes, canals, ponds, ditches and streams of the State which were created, improved and maintained by the aid of federal, state or county money; investigation and determination of the best methods of flood control and water conservation; authorization to negotiate contracts with the Federal Government and other states for the purpose of obtaining assistance and cooperation in the accomplishment of flood control and water conservancy; and determination amd mapping of proposed conservancy and water improvement districts along with justifying the creation of the proposed districts.

Conservation Commission

House Bill 49 (S.L. 1927, Chapter 70) created the Conservation Commission. This Commission was composed of three members and assumed a major duty in addition to those in the 1925 law. This duty was the supervison, conservation and development of the water power of the State.

House Bill 85 (S.L. 1935, Chapter 70, Article 3) conferred additional duties and powers upon the Conservation Commission. Some of the duties set forth in the bill were:

1. To control, store and preserve within the boundaries of the State, all waters in the State which may be stored within the State in any manner whatsoever, for any useful purpose, under the authority and control of said Commission, and to use, dispose and sell the stored water within the boundaries of the State, except as to such waters duly appropriated to private, municipal or public use.
2. To control rivers, creeks, ponds and lakes, to prevent or aid in the prevention of, damage to person or property from such harmful waters within the State of Oklahoma.
3. To acquire by gift or gratuitous grant, any and all property, real, personal or mixed, or any estate, or interest therein situated within the State of Oklahoma, necessary to the exercise of the powers, rights, privileges, and functions conferred upon the Commission.

Oklahoma State Planning Board

Senate Bill 64 (S.L. 1935) created the Oklahoma State Planning Board. This board consisted of seven members and was responsible for all resource development and planning in the state.

Oklahoma Planning and Resources Board

Senate Bill 108 (S.L. 1936-37, Chapter 24, Article 17) created the Oklahoma Planning and Resources Board. Section 3 of the Act consolidated the duties of the Conservation Commission, Oklahoma Forest Commission and the Oklahoma State Planning Board within the new Planning and Resources Board. The Act set up the Division of Water Resources within the Board and increased the Board's membership from seven to nine.

Senate Bill 111 (S.L. 1939, Chapter 24, Article 17) reduced the number of members to five: the Governor, the State Budget Officer, and three citizen members appointed by the Governor with the advice and consent of the Senate. This bill also gave the Board exclusive administrative control over all state parks, state lakes and land owned by the state for recreational purposes.

Oklahoma Water Resources Board

House Joint Resolution 520 (S.L 1955) provided for a water study committee composed of State Legislators and citizen representatives of agriculture, industry, municipalities and recreation, fish and wildlife. The committee reviewed Oklahoma's water problems and recommended the establishment of a separate agency responsible for the administration of water rights, negotiation of federal contracts and development of state and local plans to assure the most effective use of the State's water resources.

Senate Bill 138 (S.L. 1957, Title 74, Chapter 23, Section 3) transferred the water related duties of the Planning and Resources Board to the Oklahoma Water Resources Board and provided for a seven-member Board.

House Bill 1073 (S.L. 1963, Chapter 336, Section 1) created the Oklahoma Water Conservation Storage Commission consisting of the same membership as the Water Resources Board. This commission had the authority, if the maximum conservation storage in a reservoir site could not be contracted for between the Federal Government and local interests, to provide funds to insure the site's optimum development. The Commission could issue investment certificates from the Water Conservation Storage Fund as provided under the Act.

A continuing study of Oklahoma's water laws, recommendations and proposals was provided for in 1957 (82 O.S. Supp. 1978, §1085.14). Beginning in 1969, the Water Law Subcommittee and the Citizens Advisory Committee under the Legislative Council's Committee on Conservation and Economic Development, began an effort to collect, simplify and recommend recodification of the existing water law. The result of this work was introduced in the 1972 legislative session in the form of three Senate bills and six House bills, with seven of the nine bills passing that year. The Irrigation District Act was held for interim study and passed in the 1973 session. The Conservancy and Master Conservancy District revision bill was not adopted and thus this Act remains more or less in its original form.

House Bill 1596 (S.L. 1972, Chapter 253) increased the membership of the Oklahoma Water Resources Board, and consequently the Water Conservation Storage Commission, to nine members, one member being appointed from each of the six Congressional Districts of the State as they existed in 1957, and three members appointed at large.

Senate Bill 138 (S.L. 1977, Chapter 9), known as the "Oklahoma Sunset Law", provided for termination of the Water Conservation Storage Commission as created by House Bill 1073 (S.L. 1963, Chapter 336, Section 1) on the 1st day of July 1978 and the powers, duties and functions to be abolished one year thereafter. However, Senate Bill 215 (S.L. 1979, Chapter 247) transferred all existing obligations of the Oklahoma Water Conservation Storage Commission to the Oklahoma Water Resources Board effective July 1, 1979. The stated purpose of this bill was to provide or assist in providing for the acquisition, development and utilization of storage and control facilities of the waters of the state for the use and benefit of the public and for the conservation and distribution of water for beneficial purposes in or from reservoirs or other storage facilities within Oklahoma by the United States or Oklahoma or any agency, department, subdivision or instrumentality thereof.

OKLAHOMA GROUND WATER LAW

Early Ground Water Laws and Court Decisions

The first Legislative Assembly of the Territory of Oklahoma, in 1890, enacted a statute with regard to ground water which provided:

> "The owner of the land owns water standing thereon, or flowing over or under its surface, but not forming a definite stream. Water running in a definite stream, formed by nature over or under the surface, may be used by him as long as it remains there; but he may not prevent the natural flow of the stream, or of the natural spring from which it commences its defintes course, nor pursue nor pollute the same."

This Section was amended in 1963 to include the provision that "The use of ground water shall be governed by the Oklahoma Ground Water Law". (Title 60 O.S. 1971, §60).

The Oklahoma Supreme Court, in Canada v. Shawnee, 179 Okl. 53, 64 P.2d 694 (1936, 1937), had occasion to decide what principle or principles of law should govern the diversion and use of percolating water. Although the 1890 statute declared that the owner of land owns the water flowing under its surface but not forming a definite stream, the Court in Canada v. Shawnee declared that:

> "By whatever is meant when the statute says that the landowner 'owns' that elusive and unstable substance, percolating water, beneath his land, it must likewise be true that the adjacent landowner is given the same with respect to that which underlies his land. If the owner invades the natural movement, placement, and percolation of such water by creating artificial suction with powerful motor driven pumps, it is not long until he is taking that water which was but a moment before 'owned' by his neighboring landowner. We do not say that this is forbidden, so long as the taking is reasonable; but we do say that it exposes the futility of attempting to justify the complete exhaustion of a common supply of water on the ground that the landowner who has taken it all 'owned' that part thereof underlying his land when the operations commenced. His neighborlikewise had an ownership.

In a later case that involved the right of a municipality to take ground water under the law of eminent domain, the Supreme Court referred to a number of pertinent statutes, including the reenacted Territorial statute according ownership of water to the owner of the land, and stated: "In view of what we have heretofore said, we should not give these legislative acts a too limited construction." (Bowles v. Enid, 206 Okl. 245 P.2d 730, 1952).

As to the classification of ground waters, the Supreme Court in Canada v. Shawnee, supra, stated:

> "In legal consideration subterranean waters are divided into two classes: (1) Percolating waters, and (2) underground streams. Percolating waters are those which seep, ooze, filter, and otherwise circulate through the subsurface strata without definite channels. Undergrond streams are simply what their name implies; water passing through the ground beneath the surface in defined channels.
>
> "Different rules are ordinarily prescribed for the two classes of water. The cases and authorities are generally agreed that subterranean water will be presumed to be percolating water unless it is definitely shown to be of the other class. There was not such showing here, and the parties concede that this action is governed by the rules applicable to percolating water."

In this same case, the Supreme Court discussed the right to use percolating water and adopted what it considered to be the proper version of the rule of reasonable use which was set forth in two paragraphs from the syallabus by the court as follows:

> "3. The owner of land may draw from beneath its surface as much of the percolating waters therein as he needs, even though the water of his neighbor is thereby lowered, so long as the use to which he puts it bears some reasonable relationship to the natural use of his land in agricultural, mining, or industrial and other pursuits, but he may not forcibly extract and exhaust the entire water supply of the community, causing irreparable injury to his neighbors and their lands, for the purpose of transporting and selling said water at a distance from and off the premises.
>
> "6. Section 11785, O.S. 1931, vesting ownership of percolating water in the owner of the land above it, does not thereby vest said owner with the right to such an unreasonable use as will enable him to destroy his neighbor's property by forcibly extracting and exhausting the common supply of water for sale at a distance; such use being subject to the same restrictions as are imposed upon

ownership of other classes of water."

Portions of the opinion in Canada v. Shawnee, supra, have been quoted with approval in many later cases and no doubt this decision played a role in the adoption of the 1949 Oklahoma Ground Water Law.

Water as a Mineral

Webster's Seventh New Collegiate Dictionary (1971), page 539, defines "mineral" as:

> "Any of various naturally occurring homogeneous substances (as stone, coal, salt, sulfur, sand, petroleum, water, or natural gas) obtained for man's use usually from the ground."

While, on page 1006, "water" is defined as:

> "A noun; the liquid that decends from the clouds as rain, forms streams, lakes, seas and is a major constituent of all living matter and that is odorless, tasteless, very slightly compressible liquid oxide of hydrogen...; a natural mineral water..."

It has been argued that water is a mineral which should be included in a reservation of all minerals. The Oklahoma Supreme Court has declared that, in a technical sense, water is a mineral (Vogel et al. v. Cobb, 193 Okl. 64, 141 P.2d 276, 148 A.L.R. 774, 1943). However, the Oklahoma Supreme Court, in Mack Oil Company v. Lawrence, Okl. 389 P.2d 955 (1964), determined that a conveyance with "all mineral rights reserved" does not reserve the natural waters underlying the land and that, therefore, such waters remain legally attached to the surface of the realty involved. The Court limited this determination by stating that the "fact that the conveyance of the surface rights carried with it both the soil and underground water did not invest the surface owner with such a possessory right as to deprive holders of the mineral rights to the use of the water under the land for purposes necessary and incidental to their own operations theron."

It is thus well established in Oklahoma that, while the holders of mineral rights are entitled to use such ground water as may be necessary to produce other minerals, the ownership of such water would normally remain in the surface owner absent an express conveyance of same.

The 1949 Ground Water Law

The 1949 Ground Water Law provided for a system of court adjudications of existing rights in and to ground water. Such adjudications were predicated upon ground water surveys and compilations of data respecting then existing ground water rights. Beyond the adjudication of existing ground water rights, which adjudications were primarily based upon priorities of claims to ground water, the appropriation of ground water by an individual required a permit from the Board.

One very significant aspect of legislative policy embodied within the 1949 Ground Water Law was the policy of total conservation and limits placed upon the amount of ground water which could be placed to beneficial use by appropriation. Section 1007 of the law required the Board to determine the safe annual yield of a ground water basin, the same to be measured by the average annual recharge of the basin. Section 1013 prohibited the issuance of any ground water appropriation permits which would authorize the extraction and use of ground water from a basin where such an appropriation and use would result in depletion above the average annual ratio of recharge. Simply stated, the 1949 law envisioned an administrative regulatory system through which the available ground water resources would never be depleted, i.e. that the authorized appropriation and use on a yearly basis would not exceed the average annual recharge to the basin and only the "safe annual yield" of the basin could be withdrawn.

The 1972 Ground Water Law

Oklahoma's statutory system of ground water use regulation underwent major revision in 1972 (effective July 1, 1973), and the current system of regulation largely consists of the 1972 statutory framework with some minor amendments since that date.

The state policy which the 1972 ground water legislation intended to implement was stated as follows:

> "It is hereby declared to be the public policy of this state, in the interest of the agricultural stability, domestic, municipal, industrial and other beneficial uses, general economy, health and welfare of the state and its citizens, to utilize the ground water resources of the state, and for that purpose to provide reasonable regulations for the allocation for reasonable use based on hydrologic surveys of fresh ground water basins or subbasins to determine a restriction on the production, based upon the acres overlying the ground water basin or subbasin."

A 1978 amendment narrowed the exemption from the Act which had previously applied to the taking, using or disposal of water trapped in producing and nonproducing mines by depleting the word "nonproducing".

The major features of Oklahoma's current Ground Water Law, codified as 82 O.S. Supp. 1979, §§1020.1-1020.22, combine aspects of individual personal property ownership in ground water and a regulatory scheme of ground water reasonable use and regulation. Under the provisions of 60 O.S. 1971, §60, it is acknowledged that one may possess individual ownership in one's ground water, that is water flowing under the surface of the land. Such ownership and use, however, is subject to the early adopted American rule of reasonable use and the regulatory conditions and restrictions imposed by statute (Canada v. City of Shawnee, 179, Okl. 53, 64 P. 2d 694, 1936).

Under the provisions of 82 O.S. Supp. 1978, §1020.21, a municipality has the authority to regulate or permit the drilling of domestic and industrial water wells within its corporate limits. It is further provided that a muncipality may use the water allocated to the platted land within its corporate limits provided water can be made available to the platted land, a permit is obtained from the Board, the wells are located not less than 600 feet within its limits and the wells are drilled on such platted land. The Board's rules and regulations provide that a municipality has the authority to regulate and/or permit the drilling of domestic wells within its corporate municipal limits, with the Board having jurisdiction over the drilling of wells other than those for domestic purposes. Municipalities and the Board have concurrent jurisdiction to regulate and/or permit industrial wells within corporate municipal limits.

The Board's rules and regulations provide that ground water basins or subbasins may be artificially recharged but pollution and/or waste of water as set forth in 82 O.S. Supp. 1972, §1020.15 must not occur. Other than for domestic use, the use of water for this purpose requires a permit.

Hydrologic Surveys and Maximum Annual Yield Determinations

Oklahoma Law requires the Board to make hydrologic surveys and investigations of each fresh ground water basin or subbasin and, upon their completion, to make a determination of the maximum annual yield of fresh water to be produced from each ground water basin or subbasin (82 O.S. Supp. 1972, §1020.5). These hydrologic surveys must be updated at least every ten years at which time the Board may increase the amount of water allocated but may not decrease an allocation. Once a hydrologic survey has been completed and a tentative maximum annual yield established for the basin or subbasin, the Board is required to hold hearings and make copies of the survey available to interested persons. After the hearings are completed the Board makes its final determination as to the maximum annual yield of water in the basin or subbasin to be allocated to the overlying land, based upon a minimum basin or subbasin life of 20 years.

Prior Rights to Ground Water

In establishing the total discharges to be used in determining maximum annual yields the Board must make a determination of those persons having prior rights to ground water as of July 1, 1973, the effective date of the 1972 law. The criteria and procedure for determining prior rights are set forth in detail in Chapter VIII of the Board's rules and regulations. These prior rights, once established, have priority over any rights acquired subsequent to July 1, 1973, and are prioritized among themselves, but do not include the right to be protected by requiring junior right holders or ground water rights acquired subsequent to July 1, 1973, to curtail production of ground water unless the prior right holder asking for that relief proves that such relief is necessary to prevent material impairment of his prior right and that such relief will in fact materially benefit the exercise of his prior right.

Waste of Ground Water

Title 82 O.S. Supp. 1972, §1020.15, provides that the Board shall not permit any fresh ground water user to commit waste by:

1. Drilling a well, taking, or using fresh ground water without a permit, except for domestic use;
2. Taking more fresh ground water than is authorized by the permit;
3. Taking or using fresh ground water in any manner so that the water is lost for beneficial use;
4. Transporting fresh ground water from a well to the place of use in such a manner that there is an excessive loss in transit;
5. Using fresh ground water in such an inefficient manner that excessive losses occur;
6. Allowing any fresh ground water to reach a pervious stratum and be lost into cavernous or otherwise pervious materials encountered in a well;
7. Permitting or causing the pollution of a fresh water strata or basin through any act which will permit fresh ground water polluted by minerals or other waste to filter or otherwise intrude into such a basin or subbasin;
8. Drilling wells and producing fresh ground water therefrom except in accordance with the well spacing previously determined by the Board;
9. Using fresh ground water for air conditioning or cooling purposes without providing facilities to aerate and reuse such water; or
10. Failure to properly plug abandoned fresh water wells in accordance with rules and regulations of the Board and file reports thereof.

Several cases involving ground water have been tried since the 1972 Ground Water Law became effective. The Supreme Court decision in Lowrey v. Hodges, Okl. 555 P.2d 1016, 1976, specifically involved the subject of waste. The trial court had reversed a Board Order granting a temporary permit and stated that in its judgement appellants proved, as required by 82 O.S. Supp. 1975, §1020.9, that 1) they were owners of the land; 2) the land overlies a fresh water basin; and 3) attempted to prove the third requirement that the water would be put to a beneficial use, to-wit: irrigation. There was no evidence, the court said, with respect to the fourth requirement that there would be no waste and that such finding was insufficient in the absence of evidence.

Upon appeal the Supreme Court vacated the district court judgment and reinstated the Board's order granting the temporary ground water permit in question. It was noted by the Supreme Court that the Legislature had designated agricultural stability as a beneficial use and it required little imagination to recognize that the Legislature intended to include irrigation for the purpose of growing food and fiber as a beneficial agricultural use. Regarding the question of waste and the appellees contention that the record must show that waste will not occur, the Supreme Court agreed that an applicant must show what method he intended to use for irrigating a particular area and, once that information had been furnished, the Board had the authority to determine whether or not waste would occur. If the protestants thought waste would occur they would need to present that evidence to the Board for consideration. If the protestants fail to introduce evidence to substantiate occurrence of waste, and the Board finds that waste will not occur, the statute has been satisfied and further questions concerning waste must await completion of the project. The court further found that "the definitions of waste set forth in 82 O.S. Supp 1975, §1020.15 contemplated an after-the-fact finding of waste and set out the procedure for criminal prosecution, injunction, and suspension of a permit when and if it did occur".

The Attorney General of Oklahoma has ruled that the Board has the authority to grant temporary permits for irrigation water in amounts less than two acre-feet per surface acre of land owned or leased by the applicant when to grant such amount would not be of beneficial use "or would constitute waste" (Opinion No. 74-218 dated December 17, 1974).

Completing and Filing Ground Water Applications

Under the provisions of the Ground Water Law any landowner has a right to take ground water for domestic use from land owned by him without a permit. Other than this exception any person intending to use ground water must make application to the Board for a permit prior to commencing any drilling for such purposes and before taking water from any completed well previously drilled.

Notice and Hearing

After an application has been accepted for filing, a hearing date is set and a notice is prepared setting forth all of the pertinent facts of the application. The notice of the hearing must be published by the applicant once a week for two consecutive weeks. In addition, the applicant is required to give the same notice by certified mail to all immediately adjacent landowners. Any interested party has the right to protest the application.

Issuance of Permits

The Board may approve or deny the application based upon evidence presented at the hearing or from hydrologic surveys or other relevant data. Consideration is also given by the Board as to whether the lands owned or leased by the applicant overlie the fresh ground water basin or subbasin and whether the use to which the applicant intends to put the water is a beneficial use. If so, and if there is no indication that waste will occur, the Board must approve the application and issue a permit.

The Board is authorized to issue regular, temporary, special or provisional temporary permits under 82 O.S. Supp. 1979, §§1020.10-1020.11:

1. A regular permit allocates to the applicant his proportionate part of the maximum annual yield of the basin or subbasin which part is that percentage of the total annual yield of the basin or subbasin, previously determined to be the maximum annual yield, which is equal to the percentage of the land overlying the fresh ground water basin or subbasin which the applicant owns or leases.
2. A temporary permit authorizes ground water use and allocation under circumstances where the required hydrologic survey and determination of maximum annual yield has not yet been made. The water allocated by a temporary permit may not be less than two acre-feet annually for each acre of land owned or leased by the applicant in the basin or subbasin, all being subject to specified statutory exceptions.
3. A special permit is an authorization by the Board to put ground water to beneficial use in excess of amounts authorized pursuant to a regular or temporary permit, this being under special circumstances in which greater quantities of water are required. Such special permit may not be issued for a period to exceed six months but may be renewed three times.
4. In addition, a 1977 amendment to the Ground Water Law allows the issuance of provisional temporary permits. Such permits are granted by the Executive Director for a period not to exceed sixty days and are nonrenewable. The applicant is not required to give notice by publication or by certified mail. The applicant is however required by the rules and regulations of the Board to send a copy of the application to the surface landowner notifying him of the location of the well, purpose of use, and amount of water requested. Such permit holders are required to notify the Board in writing within thirty days after the expiration of the permit as to the disposition of the well covered by the permit.

Any permit issued by the Board may be cancelled upon proper notice and hearing for willful failure of the applicant to report annual usage (82 O.S. Supp. 1972, §1020.12). The Board may accept the voluntary surrender of any ground water permit by the holder thereof (82 O.S. Supp. 1972, §1020.13).

Wells and Well Drilling

Under the provisions of 82 O.S. Supp. 1972, §1020.16, all persons drilling wells, reconditioning wells, and test drilling in fresh ground water basins or subbasins must make application for and become licensed with the Board. Drillers of domestic wells are, however, exempt from this provision.

The Board has adopted minimum standards for construction of water wells, plugging of abandoned water wells and water well test holes, and capping of water wells not in use. The purpose of these minimum standards is to provide uniform rules and regulations to protect fresh ground waters of the state from contamination and waste, and to provide protection to the public by enforcing proper well construction, proper plugging of abandoned wells, and proper handling and capping of water wells.

The Board may grant a well location exception and permit the well to be drilled and completed at a location other than that previously established when it is shown that to require the drilling of a well at a prescribed location would be inequitable or unreasonable (82 O.S. Supp. 1972, §1020.18).

The Executive Director is authorized to approve an additional or replacement well when such well is determined to be necessary to fully exercise an existing right, provided the new well location is not within 600 feet of the applicant's property line unless the applicant furnishes a written statement from each adjacent landowner within 600 feet of the proposed well indicating no objection to the well (82 O.S. Supp. 1972, §§1020.17, 1020.18, 1085.2 and 1085.12).

Metering of Wells

Upon a request of a majority of landowners residing within a basin or subbasin, the Board is authorized to require that water wells be metered. Such meters shall be placed under seal and are subject to reading by the agents of the Board at any time. The applicant may also be required to report the reading of the meters at reasonable intervals (82 O.S. Supp. 1972, §1020.19).

Well Spacing Orders

The Board may, before issuing any permits in a ground water basin or subbasin, determine and order a spacing of wells which, in its judgment, may be necessary to an orderly withdrawal of water in relation to the allocation of water to the land overlying the basin or subbasin. By ruling of the Attorney General dated February 22, 1978 (Opinion No. 77-305), the Oklahoma Water Resources Board does not have authority to set mandatory well spacing prior to completion of a hydrologic survey and allocation of the ground water to the land overlying a basin or subbasin (82 O S. Supp. 1972, §1020.17).

Reports

Water use report forms are mailed during January of each year to each water right permit holder, except holders of special and/or provisional temporary permits, who must complete same and return to the Board within 30 days. This report becomes a part of each permit record. Additionally, temporary permits will not be revalidated unless the space provided on the annual water use report form is properly completed indicating that the applicant wishes the permit revalidated.

Upon transfer of ground water rights the new owner must notify the Board and submit the required transfer fee. When the owner of a water right makes a change in his mailing address he is required to provide the change and reference his ground water application number.

OKLAHOMA STREAM WATER LAW

Appropriation Doctrine

Attempts have sometimes been made to trace appropriation law from the English law, from the Massachusetts Mill Acts or from Spanish law. It is more reasonable to assume, however, that those who originated the appropriation doctrine were not versed in these laws. In 1849 the cry of "Gold!" went out and excitement rose to a frenzied peak immediately after the first nugget was picked up at Sutter's Mill. The lure of precious metal and quick riches drew thousands of prospectors to California. Lawlessness was rampant and to create order in the ungoverned public domain, the miners organized mining districts and vigilante committees which sometimes went shockingly far in meting out "justice" to those who fell under their righteous shadows. Out of the chaos rules were adopted to resolve competing mining claims and rights to the use of the water necessary to wash the gold from the gravel. Under these rules the discoverer of a mine was protected against claim jumpers with the first user of the water being protected against later takers, thus evolved appropriation law — the law of the first taker or "Law of the West", as it is sometimes known.

This law of customs was promptly adopted by the courts with the first case being tried in 1855 (Irwin v. Phillips, 5 Cal. 140). The holders of claims that lay far from a stream diverted the water over to their diggings. The owners of later claims lower on the now-dry streambed sued to require the stream to flow down in its natural channel. The California Supreme Court rejected the common law rule of riparian rights since neither party had title to the land, and, taking notice of the existing political and social conditions, held that those customs of the miners which had become firmly fixed should be followed. Among the most important of these, it said, was that of protecting the rights of those who by prior appropriation had taken the water from its natural beds and by costly artificial works had transported it for miles over mountains and ravines to supply the needs of the gold miners. The court quoted no precedents, for there were none, and a new common law form of action was born.

The evolution of this doctrine was a fortuitous event as it proved equally useful for agriculture. As mining became more competitive and less lucrative, many miners as well as newcomers to the area began farming. The doctrine protected the first settler's use of water on his land against competing claims of later settlers.

The doctrine of prior appropriation was established with respect to watercourses in Oklahoma by virtue of Territorial legislation enacted in 1897. These statutes declared the unappropriated waters of the ordinary flow or underflow of every stream, and storm or rain waters, in areas in which, because of insufficiency or irregularity of rainfall irrigation is beneficial to agriculture, to be the property of the public and subject to appropriation for the uses and purposes and in the manner provided. A proviso forbade the diversion of such flow or underflow to the prejudice of the rights of a riparian owner without his consent, except after condemnation. Grant of the power of eminent domain for condemnation of rights-of-way and of private lands needed for water development projects included "the water belonging to the riparian owner" (Terr. Okl. Laws 1897, Chapter XIX, Sec. 1). The sections of the 1897 law relating to appropriation of stream and storm waters, and to condemnation of water belonging to the riparian owner, were omitted from the Revised Laws of 1910, and were thereby repealed.

In 1905 a more comprehensive procedure for appropriating water under the supervision of Territorial officials was provided. The law of prior appropriation has undergone considerable development since that early legislation, but the fundamental principles of the law remain.

The Oklahoma Supreme Court in 1907 decided a case in which the parties were appropriative claimants who had not proceeded under statutory authority, but who based their claims "upon the general rule of law applicable to such cases" (Gates v. Settlers' Mill., C. & R. Co., 19 Okl. 83, 91 P. 856). The court applied to the facts of the case the general Western law of priority of appropriation, without construing either of the statutes. Specific principles accepted and applied in deciding the controversy were that: To acquire an appropriative right to the use of water of a public stream, there must be construction of a ditch, diversion of water into the ditch and conveyance to the place of use, and actual application of the water to a beneficial use. Reasonable diligence must be pursued throughout and failure to do so works a postponement of the priority as against a later appropriator whose right has attached pending completion of the first appropriator's right. Otherwise, the first in time has the better right, that is, priority over later appropriators. A subsequent appropriator, however, may obtain a right to surplus water in the stream above the quantity previously appropriated, which right will be superior to an attempted enlargement of the first appropriator's right. Thus the court accepted, among other things, the fundamental principle of priority of appropriation based upon priority in time of acquiring the right.

The Supreme Court in two subsequent cases construed and applied provisions of the 1905 statute relating to the acquirement of appropriative rights (Gay v. Hicks, 33 Okl. 675, 124 P. 1077, 1912; Owens v. Snider, 52 Okl. 722, 153 P. 833, 1915). The court's interpretation resulted in the adoption of a requirement unique in western water law, namely, that the state administrative agency had no authority to issue a permit for the appropriation of water for irrigation purposes unless and until a hydrographic survey and an adjudication of existing rights was made of the stream system on which the appropriation was sought.

Thus, Oklahoma Supreme Court decisions have recognized the appropriateness of applying the appropriation doctrine under Oklahoma conditions They have also construed important parts of the statutory procedure relating to acquirement of appropriative rights.

Riparian Doctrine

The riparian doctrine was purportedly brought to this countrv by two American jurists, Story and Kent, who took it from the French civil law. That their work formed the basis for the introduction of the riparian doctrine into the English common law was concluded by a noted authority in the field of water law, Samuel C. Wiel ("Water Rights In the Western States", Edition 3, Vol. II, San Francisco, 1911). The doctrine was first laid down in the English law in 1833. Having thus been received into the English common law, the riparian doctrine eventually became the law in several of the western states that adopted the common law of England.

The common-law doctrine of riparian rights originally accorded to the owner of land contiguous to a stream the right to have the stream flow by or through his land undiminished in quantity and unpolluted in quality — with one exception. The exception was that any riparian owner might take whatever water he needed for his so-called natural uses, that is, domestic and household purposes and the watering of animals necessary to the sustenance of the farm family. Irrigation, a consumptive and so-called artificial use, was not at first contemplated, but came to be accepted as a proper riparian use. No landowner could monopolize the water for irrigation. His use for that purpose had to be reasonable in relation to the similar needs of all other owners of land contiguous to the stream.

The conflict between riparian and appropriative water rights in the western states came about primarily because, in those western states that recognized both types of rights, the water rights of the lands that bordered streams were recognized as superior to those of noncontiguous lands. With the development of the country and the growing competition for water, it was inevitable that controversies should arise between owners of lands riparian to a stream, and persons who wished to extend the use of the waters to areas back from the channel, thereby increasing the usefulness of the overall water supply.

Riparian and Appropriative Rights in Oklahoma

Title 60 O.S. 1971, §60, provides: "The owner of the land owns water standing thereon or flowing over or under its surface but not forming a definite stream. The use of ground water shall be governed by the Oklahoma Ground Water Law. Water running in a definite stream, formed by nature over or under the surface, may be used by him for domestic purposes as defined in Section 2(a) (82 O.S. Supp. 1979, §105.1(b) as long as it remains there, but he may not prevent the natural flow of the stream, or of the natural spring from which it commences its definite course, nor pursue nor pollute the same, as such water then becomes public water and is subject to appropriation for the benefit and welfare of the people of the State, as provided by law; provided, however, that nothing contained herein shall prevent the owner of land from damming up or otherwise using the bed of a stream on his land for the collection or storage of waters in an amount not to exceed that which he owns, by virtue of the first sentence of this Section so long as he provides for the continued natural flow of the stream in an amount equal to that which entered his land less the uses allowed in this Act; provided further, that nothing contained herein shall be construed to limit the powers of the Oklahoma Water Resources Board to grant permission to build or alter structures on a stream pursuant to Title 82 to provide for the storage of additional water the use of which the land owner has or acquires by virtue of this act."

"Domestic use" by law means the use of water by a natural individual or by a family or household for household purposes, for farm and domestic animals up to the normal grazing capacity of the land, and for the irrigation of land not exceeding a total of three acres in area for the growing of gardens, orchards, and lawns (82 O.S. Supp. 1972, §105.1B.).

Title 60, §60, is a modification of a statute passed in 1890 by the First Territorial Legislative Assembly of Oklahoma which declared the right of a landowner with respect to use of water naturally occurring on his land. This statute, for comparison purposes, provided that:

"The owner of the land owns water standing thereon or flowing over or under its surface, but not forming a definite stream. Water running in a definite stream, formed by nature over or under the surface, may be used by him as long as it remains there; but he may not prevent the natural flow of the stream, or of the natural spring from which it commences its definite course, nor pursue nor pollute the same."

In 1897 the Territorial legislature of Oklahoma enacted a statute authorizing appropriation of water which contained a recognition of riparian rights in a proviso that flow or underflow should not be diverted to the prejudice of the riparian owner, without his consent, except after condemnation proceedings. The statute granted the right to condemn private lands and "the water belonging to the riparian owner". As previously noted, these provisions were repealed by omission from the Revised Laws of 1910.

The Oklahoma Supreme Court has quoted or cited the Territorial statute of 1890 in several cases concerning the rights of landowners to use the water of a natural stream flowing across their land (Broady v. Furray, 163 Okl. 204, 21 P. 2d 770, 1933; Grand-Hydro v. Grand River Dam Authority, 192 Okl. 693, 139 P. 2d 798, 1943; Smith v. Stanolind Oil & Gas Co., 197 Okl. 499, 172 P. 2d 1002, 1946). Undoubtedly this early statute has been important in such development of the riparian doctrine as has taken place in Oklahoma.

As recently as 1968 the Supreme Court (Oklahoma Water Resources Bd. et al. v. Central Oklahoma Master Conservancy Dist., 464 P. 2d 748, at 752) asserted that, under the provisions of 60 O.S. 1951, §60, the landowner cannot assert ownership in water "forming a definite stream". His rights therein are purely riparian.

Both systems, riparian and appropriative, have been recognized in Oklahoma as a result of legislative acts and decisions of the Supreme Court and, most significantly, the two doctrines have developed independent one of the other.

Appropriative Rights to Stream Water

Stream water in Oklahoma is, with few exceptions, public water subject to appropriation for beneficial use. Thus, the appropriation doctrine is in effect which contemplates acquirement of the right to the use of water by diverting it to beneficial use in accordance with the procedures and under limitations specified by law. An acquired appropriative right relates to a specific quantity of water and is good as long as the right continues to be exercised. The right may be acquired for any use of stream water that is beneficial and reasonable.

The bare essence of the appropriation doctrine is that a right is acquired by diverting water from a watercourse and applying it to a beneficial use. The water right carries a "priority". The basic principle employed is "first in time, first in right". The first person to appropriate water according to the procedures outlined in the statutes and put it to a reasonable and beneficial use has a right superior to or a priority over any later appropriators. In water-short years, junior appropriators with low priorities may be barred from using water and exercising their rights in order to satisfy the rights of earlier, senior appropriators.

Oklahoma Water Resources Board rules and regulations define "appropriation" as the process under 82 O.S. Supp. 1972, §105.1 et seq., by which an appropriative stream water right is acquired and a completed appropriation results in an appropriative right. Thus, an "appropriative right" is the right acquired under the procedure provided by law to take a specific quantity of public water, either by direct diversion from a stream, an impoundment thereon, or a playa lake, and to apply such water to a specific beneficial use or uses.

An appropriative right is appurtenant to the tract of land in connection with which the right was acquired but, under procedures set forth in the statutes, may be severed and simultaneously transferred to become appurtenant to other lands. Under this same procedure provision is made for changing the place of diversion, storage or use.

An important amendment to the Stream Water Law was made in 1963. Effective June 10 of that year the Oklahoma Water Resources Board was authorized to make necessary surveys and gather data for the proper determination of all persons using water throughout the state for beneficial purposes in order to establish vested or appropriative rights to stream water without the lengthy court adjudications contemplated in the earlier law. The criteria or basis for determining appropriative priorities was set forth in the law. These determinations were made for all stream systems, with the exception of the Grand River Basin, in a seven-year period between 1963 and 1969.

Purposes For Which Water May Be Appropriated

As set forth in the Board's rules and regulations, the purposes for which the public waters of the state may be appropriated are agriculture, irrigation, mining, secondary oil recovery, milling, manufacturing, power production, industrial purposes, the construction and operation of water works for cities and towns, stock raising, public parks, game management areas, propagation and utilization of fishery resources, recreation, housing developments, pleasure resorts, artificial recharge of a ground water basin or subbasin, water quality control, or any other beneficial uses.

Except for the preference given to domestic use in 82 O.S. Supp. 1972, §§105.2 and 105.12, the statutes do not establish any system of preferential use among the different beneficial uses of water.

Completing And Filing Stream Water Applications

Oklahoma statutes provide that any person, firm, corporation, state or federal governmental agency, or subdivision thereof, intending to acquire the right to the beneficial use of any water shall, before commencing any construction of works for such purposes or before taking same from any constructed works, make an application to the Board for a permit to appropriate such water, with the notable exception that water for domestic use is exempt from such requirement (82 O.S. Supp. 1972, §105.9). "Domestic use" is defined as the use of water by a natural individual or by a family or household for household purposes, for farm and domestic animals up to the normal grazing capacity of the land, and for the growing of gardens, orchards and lawns (82 O.S. Supp. 1972, §105.1).

The initial step in obtaining an appropriative right to the use of stream water consists of filing an application on forms furnished by the Board.

Every application is assigned a priority date, this being the date the water right application is received by the Board. This date is extremely important as it determines the priority between earlier or senior appropriators and later or junior ones. Again, it is first in time, first in right

If the application is for irrigation of land not owned by the applicant, the name and address of the owner must be furnished along with either a valid lease or written consent of the owner. If the applicant does not own the land at the point of diversion, the permit is issued with the condition that the applicant must provide, within a reasonable time as determined by the Board, an easement, license, or other evidence that the water can be put to beneficial use.

The total amount of water to be appropriated per calendar year is stated in acre-feet and the rate of diversion indicated in gallons per minute. The purpose or purposes for which the water is to be diverted must be noted and if the water is to be used for more than one purpose, the specific amount to be used for each individual purpose is to be clearly set forth. The applicant must also clearly state the name of the water supply from which it is proposed to divert water and the method of diversion.

Amount of Water Allowed

Based upon custom and practice, the Board has established and historically applied a reasonable use criteria of two acre-feet of stream water per acre to be irrigated. An exception may be made, however, if an applicant can show a reasonable need for additional water. Applicants for other beneficial uses of water are not restricted as to amount if the Board determines that water is available for the appropriation. In some instances the applicant may be asked to demonstrate or justify a need for the amount of water requested.

Notice and Hearing

After the application has been duly filed and accepted a date is set for a public hearing and a notice setting forth all the pertinent facts in the application is prepared by the Board to be published by the applicant once a week for two consecutive weeks in a newspaper of general circulation in the county of the point of diversion and within the adjacent downstream county. The last notice must be published at least ten days prior to the date of the hearing. At its discretion, the Board may require the notice to be published in additional counties to insure that adequate notice is given. The applicant is responsible for the accuracy of the published notice and must bear the cost of publication in the newspaper.

Interested persons may appear at the hearing in protest of any application. Hearings are conducted in accordance with the Administrative Procedures Act and the Board's rules and regulations.

Issuance Of Permits

The application is either approved or denied by the Oklahoma Water Resources Board based upon the following determinations found in 82 O.S. Supp. 1972, §105.12:

1. There is unappropriated water

available in the amount requested;

2. The applicant has a present or future need for the water and the use is a beneficial use; and

3. The proposed use does not interfere with domestic or existing appropriative uses.

In addition, in the granting of water rights for the transportation of water for use outside the originating stream system, applicants within the stream system have a right to all of the water required to adequately supply the beneficial needs of the water users therein and the Board is required to review such needs every five years.

Upon approval of an application, a permit is issued which sets forth the amount of water granted, any use conditions, and the time within which the water shall be utilized.

The Board is authorized to issue four types of stream water permits (82 O.S. Supp. 1972, §§105.1 and 105.13):

1. A regular permit which authorizes the holder to appropriate water on a year-round basis in an amount and from a source approved by the Board.

2. A seasonal permit which authorizes the holder to divert available water for specified time periods during the calendar year.

3. A temporary permit which authorizes the appropriation of water in an amount and from a source approved by the Board, is valid for a time period not to exceed three months, does not vest in the holder any permanent right, and may be cancelled by the Board in accordance with its terms.

4. A term permit which authorizes the appropriation of water in an amount and from a source approved by the Board for a term of years which does not vest the holder with any permanent right and which expires upon expiration of the term stated in the permit.

Denial Of Permit

If an applicant fails to meet any of the statutory requirements stated above, the Board must deny the permit and the applicant is notified. If denial is on the basis that water is not available in the amount applied for but is available in a lesser amount, and all of the other requirements have been met, the applicant is notified of the amount available and is entitled to amend the application and request the lesser amount. Such request must be returned to the Board by certified mail within 15 days following receipt of the notice of denial. Upon receipt of the amended application, the Board must approve the application for the lesser amount at its next scheduled meeting. This same rule applies when a permit is denied on the basis that the applicant has not demonstrated a present or future need for the water applied for. Request for amendment by an applicant does not waive the right to appeal the denial of the original application for a permit (82 O.S. Supp. 1972, §105.14).

Construction Of Works

Under 82 O.S. Supp. 1972, §105.15, any permit issued by the Board shall expire unless the applicant begins construction of works within two years of permit issuance. Beginning construction consists of purchasing equipment, beginning construction of dam or diversion works, or preparing land. Construction plans may be amended at any time upon written request and Board approval, but such changes do not extend the time for construction or placing the water to use beyond that authorized in the permit. The law provides for an extension of time for beginning construction for good cause shown, such as engineering difficulty or other valid reason over which the applicant has no control, but such extension cannot exceed two years unless a national emergency is found to exist.

Within 10 days following completion of the works the owner must give notice of such completion. Then a completion inspection may be made by the Board to determine the actual capacity of the works as well as their safety and efficiency. If not properly constructed, a reasonable time is allowed to make necessary changes and the certificate of completion is withheld until such changes are made. In addition, the Board may postpone the priority under the permit until such time as the works are actually completed and approved by the Board and any applications subsequent in time shall the benefit of such postponement of priority (82 O.S. Supp. 1972, §105.25).

Time For Putting Water To Beneficial Use

The permit holder has a period of seven years to put the full amount of stream water applied for to beneficial use. However, if it appears that the proposed project, improvement or structure will promote the optimal beneficial use of water in the State and it further appears that the total amount of water cannot be put to beneficial use within seven years, then the Board is authorized, based upon a schedule of use submitted by the applicant and, where appropriate, supported by population data from the State Employment Security Commission, to provide in the permit a schedule of time within which certain percentages of the total amount shall be put to use. This extended schedule of use, however, shall not exceed the useful life of the project or, where such useful life is indeterminate, beyond 50 years from the date of the permit (82 O.S. Supp. 1972, §105.16).

Loss Of Right Under Permit

Water not put to beneficial use in whole or in part as provided by the terms of the permit is forfeited by the permit holder and becomes public water available for appropriation under the provisions of 82 O.S. Supp. 1972, §105.17. Upon such a finding the applicant is notified by certified mail that a loss of right hearing will be held at which time he may appear and show cause why the right should not be declared to have been lost from nonuse. Failure of the Board to determine that a right to use water has been lost by nonuse, however, does not in any way revive or continue the right. (82 O.S. Supp. 1972, §105.18).

Reports

Annual water use surveys are conducted by the Board. Cards to report water use are mailed in early January which are to be completed and returned by March 1. This information not only helps the applicant protect his water right but also provides valuable information for the Board's use in maintaining a record of the amount of water used in Oklahoma.

Transfer of water rights and changes in address must be reported to the Board.

Miscellaneous Provisions in The Stream Water Law

Stream water statutes provide that the owner of works for the storage, diversion or carriage of water containing water in excess of his beneficial use needs is required to deliver such surplus water at reasonable rates to parties entitled to the use of water for beneficial purposes (82 O.S. Supp. 1972, §105.21).

Water turned into any natural or artificial watercourse by any party entitled to the use of such water may be reclaimed below and diverted therefrom by such party, subject to existing rights and less such allowance for losses as may be determined by the Board. Anyone wishing to reclaim such water using the bed and banks of any stream for conveyance must file an application with the Board setting forth the particulars of the diversion (82 O S Supp. 1972, §105.4).

Ownership Of Water

Under the provisions of Title 60 O.S 1971, §60, the owner of land owns water standing thereon, or flowing over or under its surface but not forming a definite stream. Water running in a definite stream over or under the surface may be used for domestic purposes as long as it remains there but he may not prevent the natural flow of the stream, or of the natural spring from which it commences its definite course "as such water becomes public water and is subject to appropriation for the benefit and welfare of the people of the State."

The Oklahoma Water Resources Board is charged with administering the laws pertaining to public waters. The policy of the state regarding such administration is stated as being to provide for water storage and utilization for the use and benefit of the public, for conservation and distribution for useful purposes, and to benefit the general welfare and future economic growth of the state (82 O.S Supp. 1972, §1085.17).

There is a popular misconception that water stored in large federally built reservoirs belongs to the federal government All stream water, which includes lake water, belongs to the state. All the Federal Government owns in such projects is the structure holding the water and the land upon which it rests. Municipalities or other entities contract with the Federal Government for storage in the structure, not for the water. Anyone wishing to obtain a right to the use of such public water must make proper application to the Oklahoma Water Resources Board.

Flood Flows

The Supreme Court in the early 1900's (Jefferson v. Hicks, 23 Okl. 684, 102 P 79, 1909; McLeod v. Spencer, 60 Okl. 89, 159 P. 326, 1916) made a distinction between what it termed ordinary floods and extraordinary floods, i.e. an ordinary flood being one the repetition of which might, by the exercise of ordinary diligence in investigating the character and habits of the stream, have been anticipated, even though the repetition might be at uncertain intervals, while an extraordinary flood would be unexpected, not forseen and the magnitude and destructiveness of which could not have been anticipated and prevented.

A case decided in 1943 (Franks v. Rouse, 192 Okl. 520, 137 P. 2d 899) states in the syllabus that:

"A watercourse, in the legal sense of the term does not necessarily consist merely of the stream as it flows within the banks which form the channel in ordinary stages of water; but includes the overflow waters of such stream which extend beyond its banks in times of ordinary floods and which, at such times, are accustomed to flow down over the adjacent lower lands in a broader but still definable stream, or which flow in natural depressions, continuing in a general course, though without definable banks, back into the stream from which they came, or into another watercourse. In such case the overflow water is not, and does not become, surface water."

This rule was adopted earlier in Jefferson v. Hicks, supra, which is the earliest case in Oklahoma on this subject.

Navigable Waters

The subject of navigation and navigable waters is one of considerable proportion. Navigable waters have been defined as those waters of the United States usable as such in interstate or foreign commerce (United States v. Utah, 283 U.S. 64, 75, 1931) "when they form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other States or foreign countries in the customary modes in which such commerce is conducted by water." Navigable waters of a stream within a state, which do not conform to the definition of navigable waters of the United States, are navigable waters of that state.

In developing currently recognized criteria of navigability for determining waters subject to the paramount authority of the United States under the commerce power, the landmark case is the New River decision rendered by the Supreme Court in 1940 (United States v. Appalachian Electric Power Co., 311 U.S. 377) the Court holding that "The navigability of the New River is...a factual question, but to call it a fact cannot obscure the diverse elements that enter into the application of the legal tests as to navigability." Note has been made of statements in the New River opinion that availability of a stream for navigation must be considered in addition to evidence of navigability under natural conditions; but consideration of improvements needed to make a stream suitable for commerce, even though not completed or even authorized, may control determinations of navigability. In addition, said the Court, a waterway is not barred from classification as navigable merely because artificial aids are needed before commercial navigation may be undertaken. Limits to such improvements are a matter of degree; a balance between cost and need when the improvement would be useful. The power of Congress over commerce is not to be hampered because of the necessity for reasonable improvements to make an interstate waterway available for traffic.

The Court in New River also said that "Although navigability to fix ownership of the riverbed or riparian rights is determined...as of...the admission to statehood...navigability, for the purpose of the regulation of commerce, may later arise".

Some other points are made in the New River decision — it is not necessary for navigability that the use should be continuous. Even nonuse over long periods of years because of changed conditions, competition from railroads or improved highways, or other developments, does not affect the navigability of rivers in the constitutional sense. When once found to be navigable, a waterway remains so. And it is well recognized that the navigability of a waterway may be only of a substantial part of its course.

The navigability of streams in relation to control of their waters and ownership of their beds presents a Federal question. (Lynch v. Clements, Okl. 263 P. 2d 153, 1953). Upon admission of Oklahoma to the Union, according to the United States Supreme Court, title to the beds of navigable streams within its borders passed from the United States to the state. The passing of title was thus effected by operation of law, by virtue of the constitutional rule of equality among the states whereby each new state becomes, as was each of the original states, the owner of the soil underlying the navigable waters within its borders. However, title to the beds of nonnavigable streams did not pass to the state upon its admission to the Union. If the state has a lawful claim to any part of the bed of a nonnavigable stream, it is only such as may be incident to its ownership of riparian lands and "so of the grantees and licensees of the state". (Oklahoma v. Texas, 258 U.S. 574, 1922).

The Supreme Court further held that where the United States owns the bed of a nonnavigable stream and the upland on one or both sides, it is free when disposing of the upland to retain all or any part of the river bed. Whether in any particular instance the Government has done so is essentially a question of what the Government intended. When there is no attempt or intent to dispose of a river bed separately from the upland, then, tested by common law, conveyances of riparian tracts extend not merely to the water line, but to the middle of the stream.

The vesting of paramount control over navigation so far as foreign and interstate commerce is concerned does not destroy the concurrent and subordinate power of the state, and the state may act in the absence of action by the Federal Government. In the words of the United States Supreme Court (Coyle v. Oklahoma, 221 U.S. 559, 1911):

> "The power of Congress to regulate commerce among the States involves the control of the navigable waters of the United States over which such commerce is conducted is undeniable; but it is equally well settled that the control of the State over its internal commerce involves the right to control and regulate navigable streams within the State until Congress acts on the subject..."

Implications of the control of navigable waters were discussed by the Supreme Court in a case decided in 1941 (Oklahoma v. Guy F. Atkinson Co., 313 U.S. 508, affirming Oklahoma v. Guy F. Atkinson Co., 37 Fed. Supp. 93 (D. Okla. 1941)). This case involved primarily the constitutionality of the Act of Congress of June 28, 1938 (52 Stat. L. 1215) insofar as it authorized construction of the Denison Dam and Reservoir on Red River in Texas and Oklahoma. The Court took the view that the project in question was a valid exercise of the commerce power by Congress. While commerce was at that time limited to a portion of the river within Louisiana, nevertheless it was stated that:

> "The fact that portions of a river are no longer used for commerce does not dilute the power of Congress over them...and it is clear that Congress may exercise its control over the non-navigable stretches of a river in order to preserve or promote commerce on the navigable portions..."

Flood protection, watershed development, and recovery of the cost of improvements through utilization of power have been recognized as part of commerce control; and, said the Court:

> "...we now add that the power of flood control extends to the tributaries of navigable streams. For, just as control over the nonnavigable parts of a river may be essential or desirable in the interest of the navigable portions, so may the key to flood control on a navigable stream be found in whole or in part in flood control on its tributaries..."

and

> "the fact that ends other than flood control will also be served, or that flood control may be relatively of lesser importance does not invalidate the exercise of the authority conferred on Congress."

As the construction of this dam and reservoir was a valid exercise by Congress of its commerce power, the Court held that there was no interference with the sovereignty of the state.

Tests of navigability were discussed as some length by the United States Supreme Court in Oklahoma v. Texas, 258 U.S. 574 (1922) in reaching the conclusion that no part of the Red River within Oklahoma was navigable.

The syllabus by the Oklahoma Supreme Court in a case relating to the Arkansas River (Lynch v. Clements, Okl. 263 P. 2d 153 (1953)) contains the following:

> "...where the United States Supreme Court has judicially determined that an Oklahoma river is navigable below a certain point, although such decision and its findings may not be binding upon the parties to subsequent actions in the federal courts, this court will take judicial notice that such stream is navigable below that point, and that title to the river bed where navigable, and also previously conveyed by federal grant, vested in the State of Oklahoma upon its admission as a state."

It has been determined that the Arkansas River in Oklahoma is navigable roughly from the confluence with the Verdigris River (near Muskogee, Oklahoma) to the Oklahoma-Arkansas state line (Kerr-McClellan Navigation Channel).

Although navigability tests have been applied to the Red and Arkansas Rivers, such tests have not been applied to other streams in Oklahoma to determine if they would be navigable under Federal law.

Subject to the paramount authority of the Federal Government to control navigation and to protect the navigability of navigable streams, the right to appropriate such waters is generally recognized throughout the West. Many diversions under appropriative rights are made from navigable streams. The effect of acquisition of an appropriative right on a navigable stream is to establish the appropriator's right to make his diversion during the periods in which it does not impair the navigable capacity of the stream. That waters of navigable streams of the United States may be appropriated, subject to the dominant Federal easement, has been specifically recognized by the United States Supreme Court. The Court declared the Colorado River to be a navigable stream of the United States and recognized the privilege of the states and individuals therein to appropriate and use the water by holding that this privilege is subject to the paramount navigation authority (Arizona v. California, 298 U.S. 558, 1936).

In a determination of riparian rights in the water of navigable streams, it is necessary to distinguish 1) rights in the flow of the stream itself from 2) rights in the bed of the stream and 3) rights in the fast land contiguous to the channel (Curry v. Hill, 460 P. 2d 933, (Okl. 1969)). The Supreme Court said, in this case, that:

> "The question of whether such streams similar to the Kiamichi River were navigable in fact at least so far as fishing and use for pleasure purposes is concerned has been troublesome to the courts in various jurisdictions for many years. Our precise holding is that the Kiamichi River is an open stream, navigable in fact and can be fished on from boats if the fisherman gets on the stream without trespass against the will of the abutting owner, but the fisherman cannot fix or station trot lines on the bottom of that part of the stream owned by the abutting land owner without permission of such owner."

POLLUTION CONTROL LAWS

A Need For Water Quality Control

Oklahoma's future is highly dependent upon the quality of water it has available for use and it is imperative that the quality of the state's waters be preserved in order to assure its appropriateness for all beneficial uses.

The Oklahoma Water Resources Board is charged with knowing where water suitable for all purposes can be found, and that the quality of such water will be suitable for its intended use. The effects of municipal, industrial and agricultural growth, and the waste water associated with such growth, on the quality of each potential water supply source must be ascertained. In this regard the quality of the state's ground waters is as important, if not more so, as that of Oklahoma's surface waters.

One of Oklahoma's greatest assets is her oil and it has never been more precious than in this era of energy shortages. However, the production and storage of oil must be done with great care if the waters of the state are to be adequately protected. In earlier times the state did not insure that adequate precautions were taken, and numerous oil spills from drilling and storage areas occurred, causing extensive and long lasting pollution of the state's water resources.

As a by-product of oil and gas well drilling there is almost always salt water brought to the surface which must be disposed of. With secondary oil recovery there is an additional threat to the ground waters. By injecting water under pressure into an oil well more oil can be recovered. If salt water is used for this operation, great care must be exercised so that it will not percolate through loose, sandy soil or shale to reach a layer of fresh water. In spite of the potential problems, it should be noted that the Oklahoma Water Resources Board favors the use of salt water for this recovery, particularly in areas of the state where there is a shortage of fresh water available.

Sewage must be adequately treated before it is released into a stream. Industrial plants typically are required to have lagoons into which they can put waste water so the waste can settle out before the water can be again put into the streams.

Another way man can and sometimes does pollute the surface water is with chemicals. By using insecticides and herbicides to control objectionable insects and plants, fields are sprayed with the rain washing it into the streams. It has been found that this kind of pollution reduces and sometimes eliminates the reproduction of fish in streams. Insecticides and herbicides have also demonstrated harmful effects on humans, animals and birds

In addition to man-made pollution, the waters in several areas of Oklahoma are polluted by natural salt as discussed in Chapter IV.

Early Pollution Laws

Recognizing some of these problems, the legislature early on enacted laws (S.L. 1927, Chapter 38, page 59) concerning municipal water supplies making it unlawful to:

> "...pollute, or permit the pollution, by salt water or by crude oil or the bottom settlings thereof, or by sulphur water or any other mineral water or by the refuse or the products of any well or mine, of any stream, pond, spring, lake or other water reservoir fit to be used, and used as a water supply by an incorporated city or town by which said water is rendered unfit for use as a water supply for municipal purposes. In any case in which a municipal water supply has been so polluted prior to the passage of this Act and such pollution is suffered to continue after the passage of this Act the same shall be deemed as unlawful pollution as herein defined."

The Act provided a right of action for damages to incorporated cities and towns resulting from such pollution of its water supply; the amount of compensation for the detriment caused, whether it would have been anticipated or not; and further provided "where such pollution is continued for a period of six months or more, the injury shall be regarded as permanent".

The Oklahoma Supreme Court had occasion to consider three leading cases concerning this law: 1) The measure of damages for permanent pollution (Roxana Petroleum Corporation v. City of Pawnee, 155 Okl. 141, 7 P. 2d 663, 1932); 2) Amount of damages (Arkansas Fuel Oil Co. v. City of Blackwell, C.C.A. Okl., 87 P. 2d 50, 1937); and 3) Temporary damages (Oklahoma City v. Tyetenicz, 175 Okl. 228, 52 P. 2d 849, 1935).

Water Pollution Control Act of 1955

As more and more people began using more and more water, pollution began to loom as a very great problem. Recognizing this problem, and recognizing the importance of maintaining the quality of Oklahoma's water, the Legislature passed the "Oklahoma Water Pollution Control Act of 1955" (82 O.S. Supp. 1955, §901 et seq.).

The declaration of policy with regard to pollution of state waters was set forth in §904 as follows:

> "Whereas the pollution of the waters of this state constitutes a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and aquatic life, and impairs domestic, agricultural, industrial, recreational and other legitimate beneficial uses of water, and whereas the problem of water pollution of this state is closely related to the problem of water pollution in adjoining states, it is hereby declared to be the public policy of this state to conserve the waters of the state and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the state without first being given the degree of treatment necessary to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement and control of new or existing water pollution; and to cooperate with other agencies of this state, agencies of other states and the federal government in carrying out these objectives."

§907 of the Act made it unlawful for any person to cause pollution of any waters of the state. It was further unlawful for any person to carry on certain activities without first securing a permit from the Board. Such activities were specified as:

(1) the construction, installation, modification or operation of any industrial disposal system or part thereof or any extension or addition thereto;

(2) the increase in volume or strength of any industrial wastes in excess of the permissive discharges specified under any existing permit;

(3) the construction, installation, or operation of any industrial or commercial establishment or any extension or modification thereof or addition thereto, the operation of which would cause an increase in the discharge of wastes into the waters of the state or would otherwise alter the physical, chemical or biological properties of any waters of the state in any manner not already lawfully authorized;

(4) the construction or use of any new outlet for the discharge of any wastes into the waters of the state.

In addition, §907 made it the responsibility of the State Department of Health to issue permits for the construction and installation of municipal sewage disposal systems and further provided that the Department of Health must report to the Oklahoma Water Resources Board any technical information relative to such systems as the Board might require.

Penalties for violations were provided in §912 and the right of appeal by persons who might be adversely affected was provided for in §913.

"Pollution" was defined as "contamination, or other alteration of the physical, chemical or biological properties of any natural waters of the state, or such discharge of any liquid, gaseous or solid substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful or detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life". "Wastes" were said to mean "industrial waste and all other liquid, gaseous or solid substances which may pollute or tend to pollute any waters of the state". The Act declared "waters of the state" to mean "all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon this state or any portion thereof. (82 O.S. 1961, §905.)

The powers and duties of the Board were enumerated in §906. §906(a) authorized the Board to develop comprehensive programs for the prevention, control and abatement of new or existing pollution of the waters of the state. §906(f) authorized the Board to "adopt, modify or repeal and promulgate standards of quality of the waters of the state and classify such waters according to their best uses in the interest of the public for the prevention, control and abatement of pollution".

In order to effectuate the comprehensive program required in §906(a), the Board was authorized in §908 to group state waters into classes according to their present and future best uses for the purpose of progressively improving the quality of such waters and upgrading them from time to time by reclassifying them to the extent practical and in the public interest. Hearing and published notice was required prior to classifying or reclassifying the waters or setting standards. Pursuant to this authority water quality standards were completed in 1968. The standards were revised and updated in 1973, again in 1976, and most recently in 1979. The standards are incorporated in the rules and regulations of the Oklahoma Water Resources Board and thereby into the laws of the State of Oklahoma. Any violation of their provisions gives rise to the remedies set forth in the Water Pollution Control Act.

Water Quality Coordinating Committee

With the passage of the Federal Water Quality Act of 1965 (Public Law 89-234) the Governor of Oklahoma, by Executive Order dated January 13, 1966, created the Oklahoma Water Quality Coordinating Committee. This committee was composed of the heads of those agencies having water pollution control statutory authority who were given the additional responsibility of coordinating state water quality control activities with the 1965 Federal Water Quality Act. The agencies involved were the Oklahoma Water Resources Board, the Oklahoma State Department of Health, the Oklahoma State Corporation Commission, the Oklahoma State Department of Wildlife Conservation and the Oklahoma State Department of Agriculture.

Pollution Control Coordinating Act of 1968

The Pollution Control Coordinating Act was passed in 1968 creating the State Department of Pollution Control (82 O.S. 1971, §§932 through 942, as amended). The Act provides that the Department of Pollution Control be administered by the Pollution Control Coordinating Board which is composed of nine members as follows: The State Commissioner of Health; the President of the State Board of Agriculture; the Director of the Oklahoma Water Resources Board; the Director of the Department of Wildlife Conservation; the Chairman of the Oklahoma Corporation Commission; the Director of the Department of Industrial Development; the Director of the Oklahoma Conservation Commission; and two members appointed by the Governor with the advice and consent of the Senate who must be knowledgeable and experienced in environmental activities

The Department of Pollution Control, the administrative arm of the Pollution Control Coordinating Board, is responsible for establishing a coordinated water pollution control program utilizing the existing resources and facilities in the five state agencies having water pollution control responsibilities and authority under existing statutes.

The 1972 Pollution Control Laws

The pollution control laws were codified in 1972 without significant change from the 1955 Act (82 O.S. Supp. 1972, §§926.1 through 926.13). Additional responsibilities of the Oklahoma Water Resources Board in conjunction with other state agencies are described under 82 O.S. 1971, §§932.1 et seq., as amended (Pollution Control Coordinating Act of 1968).

In addition, the Scenic Rivers Act of 1970 gave the Board and other appropriate water pollution control agencies the authority to assist in preventing and eliminating the pollution of waters within the designated scenic river areas (82 O.S. 1971, §1457).

The Board's authority in all water quality areas, either as the primary regulatory agency or in a more general oversight role, has been recognized on numerous occasions by the Attorney General. See Opinion No. 76-215 dated July 30, 1976, and more recently Opinion No. 79-205 of August 28, 1979, wherein it stated:

> "In light of the statutory provisions relative to the Water Resources Board evidencing the Legislature's intent that the jurisdiction and authority of such Board is to be auxiliary and supplemental to other pollution laws and that the Board is to provide additional and cumulative remedies to prevent, abate and control pollution of the waters of the state, it is apparent that Section 2756 (63 O.S. Supp. 1978, §2756(A)(2)) does not operate to divest the Board of its authority to act in the area of water pollution generated by oil and gas related operations..."
>
> "Accordingly, it is the opinion of the Attorney General that...63 O.S. Supp. 1978, §2756(A)(2) does not

prevent the exercise of jurisdiction by the Water Resources Board over oil and gas related pollution pursuant to its authority found in 82 O.S. Supp. 1972, §926.1 et seq. in order to prevent, abate and control the pollution of the waters of the state."

Waste Discharge Permits

Any person discharging wastes into the waters of the state, such as liquid, gasses, solids, or other waste substances or a combination thereof, resulting from any process of industry, manufacturing trade or business or from the development, processing, or recovery of any natural resource, must secure a permit from the Board before commencing such activity. A permit from the Board, however, is not required for industries discharging industrial waste directly into municipal treatment facilities nor for discharges encompassed within normal agricultural activities (82 O.S. Supp. 1972, §926.5; Rules and Regulations of the Board; 63 O.S. Supp. 1978, §2751 et seq.). In addition, under the Board's rules and regulations, any person who generates industrial waste and constructs lagoons, septic tanks, and/or total retention facilities for storage and/or disposal of industrial wastes must secure a permit from the Board before commencing such activity. Well service company terminal yards which generate waste from the washing of vehicles and/or storage of salt water, mud and other substances used in the exploration, development and production of oil and gas having a discharge or a potential for contamination of surface or ground waters of the state must also secure a permit from the Board.

Under the Board's rules and regulations, the discharge of contaminated storm water is prohibited unless it is pretreated before discharge. If contaminated storm water runoff is retained in lagoons or ponds, and is hazardous or toxic, such lagoons and ponds must be lined and proof of same provided.

Application forms are provided by the Board and must be filed in duplicate. Plant location and complete plant operations must be described in the application. A map of the area must be attached showing the location of the facilities, location of receiving waters, discharge points, lagoons, storage facilities, etc. If deemed appropriate the Board may ask for detailed plans and specifications (82 O.S. Supp. 1972, §926.4).

Notice And Hearing

When an application has been accepted for filing a date is set for a hearing and a notice is prepared setting forth all of the pertinent facts in the application. The applicant must publish the notice at his expense once each week for two consecutive weeks in the county in which the discharge is located and such other counties as the Board may designate. Hearings are conducted in accordance with the Administrative Procedures Act and the Board's rules and regulations (82 O.S. Supp. 1972, §926.3).

Permits

The Board may either approve or deny the application and, if approved, the Board may require special conditions be included in the permit.

All waste disposal permits are issued for a period of five years and may be renewed upon written application to the Board. A water disposal permit may be modified by filing an amended application by the applicant or the Board may request that an amended application be filed (82 O.S. Supp. 1972, §926 4).

The Board may require the maintenance of records relating to the operation of disposal systems. Copies of such records must be submitted upon request and any authorized representative of the Board may examine records or memoranda pertaining to the operation of disposal systems (82 O.S. Supp. 1972, §926.9).

Violations — Notice And Hearing

The Board or its duly authorized representatives has the power to enter at reasonable times upon any private or public property for the purpose of inspecting and investigating conditions relating to pollution or possible pollution (82 O.S. Supp 1972, §926.9).

82 O.S. Supp. 1972, §926.7A, provides that:

> "Whenever the Board determines there are reasonable grounds to believe that there has been a violation of any of the provisions of this act or any order of the Board, it shall give written notice to the alleged violator or violators specifying the cause of complaint. Such notice shall require that the matters complained of be corrected or that the alleged violator appear before the Board at a time and place within the affected area or within a mutually agreeable location specified in the notice and answer the charges. The notice shall be delivered to the alleged violator or violators in accordance with the provisions of subsection D of this section not less than twenty (20) days before the time set for the hearing."

Under the provisions of this section the violator is given the option of correcting the matters complained of or appearing at a hearing for the purpose of answering charges. Should the violator elect to comply with the Board's notice and requirements he must correct the matter in a manner acceptable to the Board and need not appear at the hearing. In the alternative, if a violation hearing is held, the Board affords the alleged violator or violators an opportunity for a fair hearing in accordance with the provisions of §926.8 regarding conduct of hearings.

On the basis of evidence produced at the hearing, the Board is required to make findings of fact and conclusions of law and enter its order thereon. The order of the Board becomes binding upon all parties unless appealed to the district court.

Under the provisions of 82 O.S. Supp. 1972, §926.10A, any person violating the provisions of, or who fails to perform the duties imposed by the Act, or violates any order or determination of the Board is guilty of a misdemeanor and in addition may be enjoined from continuing such violation. Each day upon which such violation occurs constitutes a separate violation. §926.10B provides:

> "It shall be the duty of the Attorney General on the request of the Board to bring an action for an injunction against any person violating the provisions of this act or violating any order or determination of the Board. In any action for an injunction brought pursuant to this section, any findings of the Board after hearing or due notice shall be prima facie evidence of the facts found therein."

Laboratory Certification

The objectives of the laboratory certification program are to provide reasonable assurance of the accuracy of scientific data submitted to the Board and to establish the use of uniform methods of water analysis. Each laboratory must employ qualified personnel and maintain adequate equipment and facilities.

CONCLUDING NOTE

Water law and its administration in Oklahoma has a long and storied history. In many respects it is a highly complex and technical area and this Chapter is but a brief highlight of the subject. For a more in-depth study of Oklahoma Water Law, attention is directed to the following publications by Joseph F. Rarick, J.S.D., David Ross Boyd, Professor of Law, College of Law, University of Oklahoma:

Oklahoma Water Law, Ground or Percolating, In The Pre-1971 Period, Reprinted from "Oklahoma Law Review", Volume 24, Number 4, November 1971.

Oklahoma Water Law, Stream and Surface, In The Pre-1963 Period, Volume 22, "Oklahoma Law Review", No. 1, February 1969).

Oklahoma Water Law, Stream and Surface, Under The 1963 Amendments, Reprinted from Volume 23, Issue No. 1 (February 1970) of the "Oklahoma Law Review".

Oklahoma Water Law, Stream and Surface, The Water Conservation Storage Commission and The 1965 and 1967 Amendments, Reprinted from Volume 24, Issue No. 1, (February 1971) of the "Oklahoma Law Review".

The Right To Use Water In Oklahoma, Copyright 1976, by Joseph F. Rarick, The University of Oklahoma Law Center.

CHAPTER III
WATER CONSERVATION IN OKLAHOMA

Due to an abundance of cheap ground and stream water in Oklahoma, scarcity has only recently been envisioned as a problem, and thus, water conservation has not been emphasized. However, due to environmental and preservation concerns, water resource development has become increasingly difficult, as well as escalating dramatically in costs of planning and construction. Ground water supplies have reached their potential in many areas, and reservoir sites that are engineeringly suitable and politically acceptable have become scarce. Federal laws such as the National Environmental Policy Act (1969), the Water Pollution Control Act (1972), the Safe Drinking Water Act (1974) and the Clean Water Act (1977) have applied additional costs by imposing more stringent quality standards on the state's waters. Furthermore, the proposed national water policy has placed special emphasis on water conservation.

Water conservation is essential to the future well being of all Oklahomans. Although not sufficient in itself, conservation offers, at least in part, one realistic means of alleviating Oklahoma's water supply problems. New water source development and the conservation of existing water must be considered jointly in any plan for supplying the entire state with adequate water.

Recurring drought periods emphasize the need for conservation. Erratic annual and monthly precipitation patterns cause streamflows to cease and storage reservoirs to dry up or become so low that their waters are rendered unsuitable for most purposes. The water levels in shallow aquifers drop, causing water wells to dry up. Conservation enforced during dry periods and the sense of emergency that prevails during droughts are soon forgotten in times of plentiful rainfall. Although water supplies continue to decline, the demand for water continues to escalate.

Shortages of available surface supplies for existing water users, depletion of subsurface reservoirs, obsolete urban systems and the increasing water demands of an expanding population combine to exert mounting pressures on existing water supplies. Water conservation, then, must be practiced regularly and consistently — in times of plenty as well as in times of drought. Since water-saving practices conserve energy, they can also have a significant impact on energy requirements. High water consumption corresponds directly to increased pumpage and high wastewater facility use, which in turn, requires additional energy.

Water conservation most often has been approached in a technical sense, i.e., the implementation of mechanical methods or techniques to reduce water consumption. However, a more comprehensive definition of conservation may be more appropriate, one involving economic and institutional constraints, such as the formation of water management districts, conjunctive use of stream and ground water and water pricing practices. This broader concept should be emphasized in the development of a statewide water conservation strategy.

POTENTIAL WATER CONSERVATION MEASURES

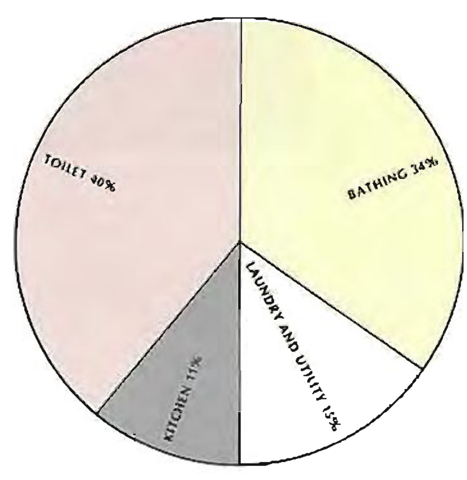
Municipal and Residential Water Conservation

There are many water conservation measures that can save significant amounts of water in the home. The following examples are only a few of many possibilities. An average family of four uses approximately 233 gallons of water each day, with 74 percent of that usage occurring in the bathroom. Toilets use more water than any other fixture in the home, consuming an estimated 40 percent of all water used indoors. By reducing the volume of water needed to flush to 3.5 gallons, as opposed to the five to seven gallons required by toilets of older design, new low-flush toilets effect great water saving. Older toilets using higher volumes can be modified through the installation of certain devices in the tank to reduce the flush volume. A brick in the toilet tank is a reliable means of reducing water volume, however carried to excess, it may deprive sewer lines of sufficient flow to drain properly. More promising is a sinkbob mechanism designed to use half the normal flush volume for removing liquid wastes, and allowing adjustment to full volume for the removal of solid wastes.

Bathing accounts for 34 percent of water consumed in the house with 60 percent of this total used in the shower. Many companies manufacture shower heads or adapters which conserve water by reducing the maximum flow rate or by producing a shower spray with a lower flow of water. Since conventional showers use up to 10 gallons per minute, and showers average five minutes in duration, water use can be reduced up to 70 percent by utilizing a flow control device which reduces the rate of flow to three gallons per minute.

Major water-using appliances in the kitchen are automatic dishwashers and garbage disposals. While older dishwasher models use 13 to 16 gallons for each 60-minute cycle, new water-saving models consume only 7.5 gallons per load. Washing and rinsing dishes by hand under a flowing stream of water is most wasteful, often consuming as much as 25 gallons. Faucet flow controls can

FIGURE 4 TYPICAL WATER CONSUMPTION IN THE HOME
Family of Four
(By Percent)



reduce up to 50 percent the rate at which water flows through the faucet.

Plumbing maintenance is an essential part of water conservation efforts because major losses of water can be traced to a water distribution system or to a consumer's system after the water has passed the home meter. An estimated 10 percent of the treated water in a utility system is wasted through such leakage. Contributing factors include broken water mains and joints, leakage from hydrants, and leakage from water utility storage and in main trunk facilities. A homeowner who wants to determine whether or not leaks are occurring in his home should turn off all water-using devices, then check the meter to insure no flow is registering.

There are other no-cost methods of conservation in the home such as using clothes washing and dishwashing machines only for full loads, taking shorter showers, using less bath water and reducing the use of disposals, among many others.

In urban areas the largest water saving outdoors can be effected by careful lawn watering. Heavier, less frequent watering encourages the development of healthy, deep-rooted grass, while overwatering wastes water and may damage grass and soil. Grass left at a longer length will remain greener and healthier and require less moisture. Water should be applied during the coolest part of the day to minimize evaporation losses.

Sweeping sidewalks and driveways rather than hosing them and washing a car from a pail instead of a hose conserve significant amounts of water. Hose attachments, moisture indicators on sprinklers and time-controlled sprinklers also contribute to outdoor water conservation.

Industrial Conservation

Industries have responded to the increased price of treated water and the huge cost of treatment after it has been used by practicing various conservation methods. Studies have shown that intake water use per unit of production has decreased markedly in the past 20 years, indicating that significant conservation measures are becoming widespread. This trend is expected to increase as technology improves and the cost of treatment continues to escalate.

The greatest use of water by industry is for dissipation of unwanted or excess heat. Water used in this cooling process is consumed through evaporation. One method of reducing consumption is to employ different means of dissipating the heat. Although they are costly, air cooling devices or dry cooling towers are alternatives. Soil warming — circulating heated industrial waters through subsurface pipes — is also a potential technique. Changing the process to reduce waste heat or putting the excess heat to other uses not only conserves water, but conserves energy. The use of sewage effluent offers a most promising means of fulfilling future cooling water requirements.

The vast amounts of water used in some industries can be reduced by substituting or altering procedures, such as those of many vegetable and fruit processors, who have replaced water-intensive peeling processes with dry peeling systems. Many procedures can be altered so that relatively clean water from one process can be reused in a process that does not require fresh water.

Water use can also be reduced by installing water conservation devices for employee sanitation, such as described previously.

Agricultural Conservation

Depletion of ground water sources has become a major concern for farmers in western Oklahoma. Without adequate irrigation water, many could be forced to revert to dryland farming, causing major reductions in crop production, lower on-farm profits, and adverse effects on the economy of the entire state. To alleviate this critical problem, agricultural water conservation should be expeditiously implemented.

Stubble mulch tillage and no-till planting keep plant residues on the soil surface to increase infiltration and reduce evaporation loss. Narrow row spacing and careful selection of the planting dates and growing practices that utilize available rainfall most effectively can also result in significant water conservation. Improved varieties of plants which require less water are also becoming available.

Weed control plays a significant role in water conservation. Water losses by weeds are highest in row crops that have not attained more than 60 percent ground cover. Water is also lost when water-loving plants (phreatophytes) such as salt cedar, cottonwood, willow and mesquite are permitted to grow in open ditches or in poorly drained areas. The consumption by phreatophytes across the state ranges from a fraction of an acre-foot of water to more than seven acre-feet per acre.

Significant water saving and other advantages can be realized by eliminating earthen irrigation ditches, a practice that reduced seepage and evaporation losses, while also reducing labor and system maintenance. Pipelines also require less land area than canals and produce more positive control in water management.

In 1977 there were 208 miles of earthen ditch and 182 miles of concrete-lined ditch in use by Oklahoma irrigators. The majority of ditch conveyance systems are in the W.C. Austin (Lake Altus) Irrigation District in Jackson County, where 1,470 miles of above-ground pipe and 1,388 miles of underground pipeline were in use in 1977.

The use of tailwater recovery systems is an effective means of conserving water. The reuse of irrigation water captured in tailwater pits not only conserves water, but keeps the highly chemically concentrated water from degrading receiving streams. The nutrients in this water can be recycled by pumps on floating platforms to remove and reuse the surplus tailwater flows.

Modification of playa lakes in the Oklahoma Panhandle is another means of conserving water that would otherwise be lost to evaporation Increasing the depth to surface area ratio reduces surface evaporation losses and makes the playa ideal for storing spring runoff and irrigation tailwaters.

The greatest single on-farm saving can be accomplished by selecting the most suitable irrigation method. Application efficiency depends on the uniform application of the water at a proper rate and at the proper time. Gravity (flood or furrow) irrigation and sprinkler irrigation are the two most common methods of applying water.

In 1978 approximately 430,400 acres, or 48 percent of the total land irrigated in Oklahoma, were irrigated by gravity application methods. Application efficiency for a typical gravity system averages about 50 percent, with a range of 30 to 75 percent efficiency. If water cannot be applied to a uniform depth over the field surface, application efficiency will decrease. High efficiency is difficult to achieve with gravity systems because of variables such as slope, duration of application, stream size and infiltration rate of the soil Unless the field is almost perfectly level, it is difficult to apply a given depth without waste.

In 1978, 52 percent of the land irrigated in Oklahoma, or 466,300 acres, was irrigated with sprinkler systems Sprinkler systems are generally more efficient than surface methods, averaging 70 percent, with a range of 55 to 90 percent. Evaporation loss from sprinklers is normally five to 10 percent of the discharge. Wind is a major factor in obtaining high efficiency. Center-pivot sprinkler systems have become popular in the past 10 years because they require little labor.

Water saving results when gravity irrigation is replaced with sprinkler systems, however, the high cost of conversion would need to be carefully evaluated.

A new technology, trickle or drip irrigation, is gaining popularity in many arid areas because it increases efficiency to near 100 percent by applying water to the base or root zone of each plant. The system uses plastic tubes with small outlets near each plant, applying smaller amounts of water and eliminating runoff and evaporation from wet soils. This method was initially used only on high value orchard crops, but its use is being extended to other fruit and vegetable crops. Results of research conducted thus far show irrigation water requirements can be reduced as much as 50 percent without appreciable loss in yield. However, capital cost of application equipment is very high compared to other methods of irrigation.

Regardless of the method, timeliness of water application is a key factor in conserving agricultural water Allowing the crops to grow under controlled stress during certain growth stages when yield is not affected, and applying water only at critical stages of plant growth is up to 50 percent more efficient than conventional irrigation timing methods. Scientific tools and assistance are now available to give the irrigator precise information on when to irrigate each field.

Wastewater Reuse and Recycling

Wastewater or sewage effluent discharged by municipalities and industries constitutes an appreciable portion of the state's available stream water resources. This effluent must be recognized as a valuable resource that can be reused or recycled to help meet growing water requirements.

Proponents list as pluses for reuse savings in money and energy, particularly in the cost of treating wastewaters to make them acceptable for discharge. However, due to the availability of high quality water, most municipalities thus far have not sought to develop a market for treated wastewater, simply disposing of it as quickly as possible.

The use of municipal and industrial effluents for irrigation is gaining greater acceptance in the state. Their high nutrients, chiefly nitrogen and phosphorus, increase agricultural yields to levels higher than those realized from conventional irrigation and fertilization. Crops considered for such fertilization must be selected by their tolerance to the contaminants, and because the soil tends to retain buildups of certain metals and salts present in the wastewater, specific limits must be established. The buildup of dissolved solids such as sodium chloride or of heavy metals cannot be tolerated by vegetation.

Many crops are presently irrigated with municipal wastewater, however, its use is not recommended for the irrigation of crops intended for human consumption. Such precautions are based on the lack of reliable information on the survival and transmission of pathogenic bacteria and viruses

The greatest undeveloped potential for reuse is that of municipal effluents by industries. Several public utility companies have built lakes to catch these return flows, and utilize the water successfully in their cooling towers. Cooling lakes can be used for recreation and fish farming, as well as aquaculture, which exhibits promise for growing aquatic species for food supplements.

Use of municipal wastewater for cooling may require additional treatment, especially if it is to be used in recirculation systems, but lower quality water has been used successfully in once-through cooling systems.

Recycling of process waters by Oklahoma industries has been limited because of the availability and abundance of high quality, inexpensive municipal water. Recycling which has been practiced has often been for the purpose of recovering wastewater components such as expensive metals. Increased consideration is being given to the reuse of industrial effluents in anticipation of escalating federal standards which propose zero pollution discharge by 1983.

As the water use increases, so will the volume of wastewater. The scarcity of new water sources, more stringent treatment requirements and increased costs of treatment will greatly influence future water reuse policy and practice.

Conjunctive Use of Stream and Ground Water

In some areas of the state, hydrologic conditions exist which make stream and ground water available for use on a complementary basis. In such areas, communities should be encouraged to employ conjunctive use practices utilizing both sources.

Such conditions are present in eastern Oklahoma, where high recharge levels and abundant rainfall produce large quantities of ground and stream waters. Ground water has not been extensively developed as a primary water source in eastern Oklahoma, and while some communities and irrigators utilize ground water, it accounts for only a small percentage of the area's total water use. Increased reliance on ground water, particularly during periods of drought, could play a significant role in future water planning.

Conjunctive use of stream and ground water can also be effectively employed in central Oklahoma, where the Garber-Wellington and Vamoosa Formations provide immense yields and stream water is also available, although it is often limited by quality considerations. Several central Oklahoma cities currently practice conjunctive use to maximize water supplies, and such use is expected to expand.

Western Oklahoma has little or no stream water available for appropriation, and the area's reliance on ground water is threatened by depletion. Thus, conjunctive use is generally not realistic in most of the west, however, the practice should be implemented in those few areas where it is appropriate.

Water Management Districts

Although local water management districts have proven highly successful in neighboring states, their worth as an effective water management and conservation tool has not yet been widely recognized in Oklahoma.

Irrigation and water resources associations have long existed in the three Panhandle counties. A countywide district for the conservation and management of Texas County's water resources was created under authority of Oklahoma law, but has not been active due to local problems associated with the assessment and administrative functions of the district. Hopefully, such problems will be resolved, allowing the district to become active and efficient in the management, development, conservation and protection of the area's valuable water resources.

Among the limited number of other irrigation or conservancy districts is the federally sponsored Altus-Lugert Irrigation District in southwestern Oklahoma, which negotiates contracts for water from Altus Lake, a Bureau of Reclamation water development project. An irrigation district exists below Canton Lake in the northwest, although it has been relatively inactive, and new districts are being organized near Waurika Lake in south central Oklahoma and below Fort Cobb Reservoir in the Washita River area of Caddo and Grady Counties. Master conservancy districts exist throughout Oklahoma, and others are being formed.

All of these local, state and federally supported districts present a viable mechanism for the efficient use, development, conservation, protection and management of the state's valuable water resources. Their increased utilization is especially important in areas of insufficient water supplies or those faced with depletion. In those areas faced with shortages, efforts must be made to maximize existing local supplies before importation of water from other areas can be considered as a realistic alternative. Thus, widespread organization of water management districts must be an integral part of any meaningful plan that proposes the development, management and intrastate conveyance of water.

Water Pricing

As with any other commodity, increasing the price is a proven and effective means of reducing water consumption. Pricing techniques to encourage the conservation of water rely primarily on the premise that as the price increases, the quantity purchased decreases. The effect of such a price change on quantity is called demand elasticity.

There is substantial elasticity in the demand for water. The price of water affects the amount consumers will demand; if the price goes up, consumers will use less water. While the response may vary between different classes of consumers, or even between individual consumers within a class, there will be a response from the customer if the price increase, is significant in relation to his income.

The response to price increases will also vary in water use categories; it will be greater in the lawn watering category than the in-house use category. In Oklahoma's water systems, consumer demands exhibit dramatic seasonal variation, with the peak demand occurring in the summer. The cost to the system of expanding to meet the peak demand has far exceeded the price charged for the water. Consumers have made decisions based on the underpriced peak water, and have increased their consumption beyond the point at which the cost and the value of output are in balance. At the same time, off-peak water is relatively inexpensive to provide, but by charging more for it, consumers are discouraged from overusing it. Water conservation can be promoted by a system of marginal cost pricing, with the consumers using to their satisfaction and the suppliers minimizing their costs.

RATE STRUCTURES

There are four basic rate structures commonly used for water pricing, and these, along with their definitions and effects on conservation, are shown in Figure 5 .

Flat rates are generally calculated by dividing total operating and capital costs for a given time

FIGURE 5 RATE STRUCTURES FOR WATER PRICING

TYPE OF RATE STRUCTURE	DEFINITION AND COMMENTS	EFFECT ON WATER CONSERVATION
Flat Rates	A fixed amount is charged per time period, regardless of water services used. Usually found in unmetered areas The rate is often varied according to the size of delivery line.	NONE
Average Uniform Rates	A constant price per unit of water is charged, regardless of the quantity used.	SLIGHT
Decreasing Block Rates	The price per unit of water decreases as the quantity of use increases. Most commonly used rate structure in Oklahoma.	ADVERSE
Increasing Block Rates	The price per unit of water increases as the quantity of use increases Rarely used in Oklahoma.	MAJOR

period by the number of customers. This method does not reward the customer who conserves water.

Average or uniform rates, commonly used by many utilities, are determined by dividing the total water produced into the total operating and annual capital costs to supply that quantity. It slightly encourages water conservation by reducing the total bill when less water is used.

Decreasing block rates, based on the premise that it costs less to service large users than small, encourage water use. This is the rate structure most commonly used in Oklahoma. It subsidizes the larger user at the expense of the small user, and is often used to attract industry to an area. The net effect of such a policy is a water use subsidy for large users.

Increasing block rates are the most effective in encouraging water conservation. As larger quantities are used, the consumer has to pay a higher increased amount for the latter portions used. Water departments in Oklahoma interested in conservation should consider the appropriateness of adopting an increasing block rate structure.

PROBLEMS ASSOCIATED WITH WATER CONSERVATION

Although water conservation must play an important role in meeting Oklahoma's future water supply needs, it cannot be considered a panacea. There are potential legal and institutional barriers to implementing conservation measures in areas of water shortage, as well as possible adverse impacts to wildlife habitat

Water conservation and reuse do not increase the natural water supply of a basin, as do weather modification or water importation Conservation practices simply permit increased beneficial use of the existing supply.

In western Oklahoma most stream water of good to marginal quality has been appropriated to existing beneficial uses, and the area's ground water supplies are being rapidly depleted. Water conservation will not provide additional water to western Oklahoma farmers, and utilizing the existing supply more efficiently through conservation will only buy time until additional water supply facilities can be planned and constructed.

Conservation can adversely impact both water quantity and quality in downstream receiving streams. All communities and industries in Oklahoma that utilize stream water sources practice a form of indirect reuse, as wastewater from treatment plants mixes with natural flows to be reused downstream. As this water is impounded, evaporated, used and reused, diverted and reintroduced into the streams again and again, chemical constituents such as sulfates, chlorides and nitrates accumulate with each cycle of use. The affect on downstream areas with already marginal quality water will prove extremely detrimental because the chemical constituents that build up with each reuse are those that are so costly to remove by treatment.

The increasing costs of treating sewage effluent to comply with state and federal discharge standards are forcing municipalities and industries to seek more economical means to consumptively use or effectively eliminate their wastewater through use of evaporation ponds and land application for irrigation. Such practices eliminate the wastewater as a source of water for potential downstream consumers. Litigation sponsored by downstream users to preserve the integrity of their supply is possible whenever conservation measures affect existing downstream waters. Although such situations have not yet developed, they can be expected as water supplies become more precious. Based on interpretation of Oklahoma's stream water law, upstream users could possibly be denied the right to totally reuse their effluent, so that downstream users granted prior or vested water rights can be assured of water supplies

Conservation practices and reuse could also adversely affect the state's ground water supplies. The shallow alluvium deposits along the banks of river channels and creek beds which are naturally recharged by streamflow have been developed extensively for municipal and irrigation uses in some areas of Oklahoma. The potential loss of streamflow from the reuse and total retention of municipal sewage effluents would diminish this recharge, thus drying up the alluvium ground water basins.

Implementation of irrigation conservation methods can exert significant adverse impact on fish and wildlife habitat as well. Waterfowl and other species dependent on wetlands and seeps would be deprived of habitats provided by conveyance losses, tailwaters and operational spills. Similar negative effects could impact on both the variety and quantity of fish and habitat for endangered species along water courses. Removal of weeds and phreatophytes to reduce incidental water losses would discourage nesting waterfowl, small animals, upland game and other animals that depend on them for food and cover.

CONCLUDING NOTE

Many ways to conserve water have been discussed, but incentives must be provided if these measures are to be implemented. Federal, state and local water agencies should encourage water conservation through public education programs and tax incentives to those who develop enduring conservation practices on their land. All state agencies should consider the soil and water conservation needs of their construction projects at the beginning of the planning phase. Conservation in both the public and private sector is vital if the life of existing water supplies is to be prolonged. Such "stretching" of the available water will pay substantial dividends, if only to provide time for new water source development.

CHAPTER IV
STATEWIDE APPRAISAL

HISTORY

Archaeologists have discovered traces of human life 10 to 15 thousand years old in the caves and ledges of northeastern Oklahoma's Ozark Mountains, making it perhaps one of the oldest inhabited areas in the United States. Still, Oklahoma did not enter the mainstream of recorded history until the arrival of the first of the Spanish conquistadores, Francisco de Coronado, in 1541 Although Coronado never found the fabled "Seven Cities of Cibola" he sought on his expedition through Oklahoma, he claimed a vast expanse of the New World for Spain.

Long before the white man came to share the treasures of the fertile land, Indians had followed the seasons and the abundance of fish and game on the banks of Oklahoma's great rivers, creeks and fresh springs. In 1682 LaSalle navigated the Mississippi River from the north to the Gulf of Mexico and claimed for France all of its drainage area – land ultimately acquired by the United States in the Louisiana Purchase of 1803.

Oklahoma possessed the potential for becoming one of the first states to be created from the Louisiana Purchase, but instead, its destiny was to be Indian Territory. In 1830 Congress passed a bill for the removal of the civilized tribes, a document that would set the Creeks, Cherokees, Choctaws, Chickasaws and Seminoles forth on the "Trail of Tears." By 1855 there were five separate Indian republics in Oklahoma, and the Reconstruction period brought the resettlement of still more tribes, until some 67 Indian tribes occupied the Territory by the end of the century.

Eager settlers coveting the lush prairies and abundant streams discovered that a 1.9 million acre section of land in the center of Indian Territory, called the Oklahoma District or Unassigned Lands, remained in the public domain. They began to demand that the Federal Government open it to them under the Homestead Act that President Lincoln had signed in 1862, granting 160 acres of public land to any settler who would cultivate it for five years. In 1889 a bill was passed opening the Oklahoma District for settlement beginning on April 22. On that date there was a frantic race for land, with Oklahoma City being established on the banks of the North Canadian River and Guthrie mushrooming along Cottonwood Creek. April 22 in 1889 was marked by stifling heat and dust and a strangling lack of water. A well was hurriedly dug at the corner of Main and Broadway in Oklahoma City, and federal troops guarded the precious water supply source.

Interest in water and water development bagan even before statehood In 1902 Theodore Roosevelt signed into law the Reclamation Act to aid the arid western states, and the following year investigations were begun in Oklahoma Territory to determine how water supplies could best benefit the area. The Eighth Legislative Assembly of Oklahoma Territory enacted the first water law in 1905, outlining the procedure for acquiring water rights, regulating the use of water and creating the post of Territorial Engineer to administer the new law.

On November 16, 1907 President Theodore Roosevelt signed the Oklahoma Enabling Act, welding into a single state the "twin territories" of white and Indian land, and that year Oklahoma became the 46th state in the Union.

Oklahoma, represented by the 46th star on the flag of the United States, has a land area of 69,919 square miles, divided into 77 counties. The largest county is Osage in northeastern Oklahoma and the smallest is Marshall in the southern portion. The state boasts wide geographical diversity, from the rolling, verdant Great Plains in the west to the rugged, wooded hills of the east. Oklahoma's contrast in land surfaces is matched by broad diversities in populations, ranging from sparsely populated Panhandle farm and ranch lands to thriving metropolitan centers in central and northeastern portions. Oklahoma City is the state's capital, and along with Tulsa, these two Standard Metropolitan Statistical Areas (SMSA) represent one-half of the state's 2,811,000 residents.

Sloping gently from northwest to southeast, Oklahoma's highest elevation is 4,973 feet above mean sea level at Black Mesa in Cimarron County, and its lowest is 305 feet near Idabel in McCurtain County. Slightly south of the geographic center of the nation, Oklahoma is bordered by Texas, Kansas, New Mexico, Colorado, Missouri and Arkansas. Two great river basins –the Red and the Arkansas and their tributaries –traverse the state from border to border and contribute to the state's wealth of water resources.

Oklahoma's abundance of resources has nurtured healthy social and economic growth. In 1977, the state's 10.7 million acres of agricultural land produced nearly $2 billion worth of crops and livestock. In that same year raw mineral production in Oklahoma was valued at $3.5 billion, with mineral industries active in 76 of the 77 counties and oil and gas produced in 71 counties. The McClellan-Kerr Navigation System on which more than 10 million tons of commodities were shipped during 1978 is just one example of Oklahoma's extensive water resource development.

CLIMATE

Oklahoma is divided into two basic climatic regions, the humid east and semiarid west. Summers are long and hot, while winters are shorter and less rigorous than those of the plains states lying farther north. However, recent winters have been increasingly severe, registering record snowfalls and temperature readings. Moist air currents from the Gulf of Mexico temper the weather during most of the year, but cool, moist air masses from the Pacific and cold, dry Canadian air masses influence Oklahoma's winter temperatures.

Maximum precipitation occurs in the spring, when thunderstorms frequently spawn the damaging funnels

FIGURE 6 CLIMATOLOGICAL SUMMARY
Combined Period of Record 1915-1974

REGION / STATION	LENGTH OF RECORD, YEARS	TEMPERATURE							PRECIPITATION (INCHES)		
		MEANS			EXTREMES						
		YEARLY AVG.	DAILY AVG.	DAILY MIN.	MAX.	(DATE)	MIN.	(DATE)	YEARLY AVG.	GREATEST DAILY	(DATE)
SOUTHEAST											
Ada	30	62.4	73.6	51.1	112	8/16/43	-6*	1/4/47	39.40	7.80	9/29/26
Atoka	30	62.6	74.6	50.5	115	8/16/43	-8	2/2/51	40.78	8.10	7/13/27
Coalgate	30	63.0	75.3	50.7	112	9/2/51	-5	1/8/40	41.15	9.54	7/15/53
Durant	30	63.3	75.3	51.2	113	8/7/56	-4	2/2/51	40.47	7.40	8/17/26
Hugo	24	63.8	75.5	52.0	110	8/5/64	-6	2/2/51	47.13	7.05	10/1/54
Tishomingo	30	62.9	75.2	50.5	120	7/26/43	-8	2/2/51	38.95	8.62	7/14/27
CENTRAL											
Oklahoma City (AP)	30	60.3	70.5	50.1	108	7/19/66	1	12/31/68	30.82	4.82	10/3/55
Shawnee	24	61.4	74.0	48.8	112	8/15/56	-6*	1/5/59	35.89	6.56	5/25/57
SOUTH CENTRAL											
Ardmore	30	64.3	75.9	52.7	110	8/16/43	-4	1/14/47	35.83	8.80	7/14/27
Duncan	23	62.9	75.0	50.8	110	8/9/46*	-8	1/3/47	32.90	9.85	5/4/55
Madill	30	63.2	74.2	52.1	111	8/5/64	1	2/2/51	39.16	6.57	6/2/57
Marietta	30	63.8	75.9	51.7	112	8/16/56	-3	1/4/47	36.04	5.83	10/12/37
Pauls Valley	30	62.5	75.1	49.9	112	8/16/56	-9	1/4/47	34.79	5.90	10/8/70
Sulphur	30	62.5	75.0	50.0	111	8/15/56	-10	1/9/44	37.47	11.61	10/8/70
Waurika	24	64.1	77.5	50.6	116	8/6/64	-5	1/23/66	30.16	4.70	4/12/67
SOUTHWEST											
Frederick	24	64.2	77.9	50.5	115	8/6/64	-4*	2/1/51	25.57	5.90	9/22/69
Hobart	24	60.6	72.7	48.4	113	7/25/54	-3*	2/1/51	24.39	5.73	9/19/65
Hollis	24	62.8	77.5	48.1	117	6/14/53	-10	1/23/66	21.53	4.66	5/17/51
Lawton	30	62.3	75.2	49.2	112*	8/3/43	-7	1/4/47	30.16	6.25	10/20/53
Mangum	24	62.2	76.5	47.8	113	8/6/64	-7	1/23/66	23.41	5.46	9/23/70
Sayre	24	60.5	74.3	46.6	114	6/14/53	-7	1/23/66	22.32	4.22	10/9/68
Walters	50	63.6	75.9	51.3	114	8/11/36	-10*	1/18/30	29.69	7.50	10/2/41
Weatherford	24	60.6	72.9	48.2	111*	8/6/53	-4*	2/1/51	27.14	6.25	9/24/59
NORTHEAST											
Bartlesville	24	59.6	72.4	46.7	115	7/14/54	-13	1/5/59	35.53	5.88	9/4/53
Miami	24	59.7	71.4	47.8	116	7/14/54	-8	12/23/63	41.76	9.15	7/7/58
Muskogee	40	61.4	72.6	50.1	114	7/14/54	-3*	12/23/63	41.92	7.16	7/15/61
Pryor	22	59.6	71.7	47.4	112	7/13/54	-9	12/23/63	37.53	5.20	7/15/61
Spavinaw	24	60.9	71.9	49.7	111	7/13/54	-8	12/23/63	41.79	8.35	8/14/61
Tulsa (AP)	30	59.7	70.6	48.8	110	8/5/64	-3	12/23/63	37.08	7.54	7/2/63
Wagoner	24	61.0	73.0	48.9	115	7/13/54	-6	12/23/63	40.76	6.15	7/15/61
EAST CENTRAL											
McAlester	30	61.9	73.3	50.5	113	8/16/43	-9	1/11/62	41.08	7.12	5/9/43
Poteau	24	62.3	74.3	50.2	111*	8/17/52	-7	2/2/51	44.67	7.82	5/14/68
NORTH CENTRAL											
Enid	30	60.3	72.0	48.7	113	7/14/54	-10	1/4/47	30.04	8.30	7/25/60
Hennessey	24	60.4	72.8	47.9	114*	8/6/64	-10	1/4/59	28.59	9.78	5/15/57
Jefferson	24	59.8	72.6	47.0	115	7/14/54	-9	1/4/59	30.01	10.00	10/11/73
Newkirk	24	59.3	71.0	47.6	117	7/14/54	-8	1/4/59	32.99	6.23	9/13/61
Ponca City	24	60.5	72.9	48.1	115	7/14/54	-5*	1/1/51	33.85	5.75	7/25/67
Stillwater	24	60.0	72.2	47.7	113	7/14/54	-6*	12/14/58	32.68	7.00	5/21/57
NORTHWEST											
Beaver	24	57.6	72.5	42.6	111*	6/28/60	-23	1/4/59	19.50	4.45	5/14/51
Goodwell	24	56.8	72.2	41.3	111*	6/28/68	-22	1/4/59	15.89	3.86	8/7/59
Kenton	24	56.0	72.2	39.8	109	6/29/57	-23	1/4/59	15.41	6.37	10/17/65
Woodward	24	59.6	73.3	45.8	111*	8/6/64	-14	1/4/59	22.98	3.82	8/28/74

*Also on earlier dates.

FIGURE 7 MEAN ANNUAL TEMPERATURE (In °F)
Period 1931-1960

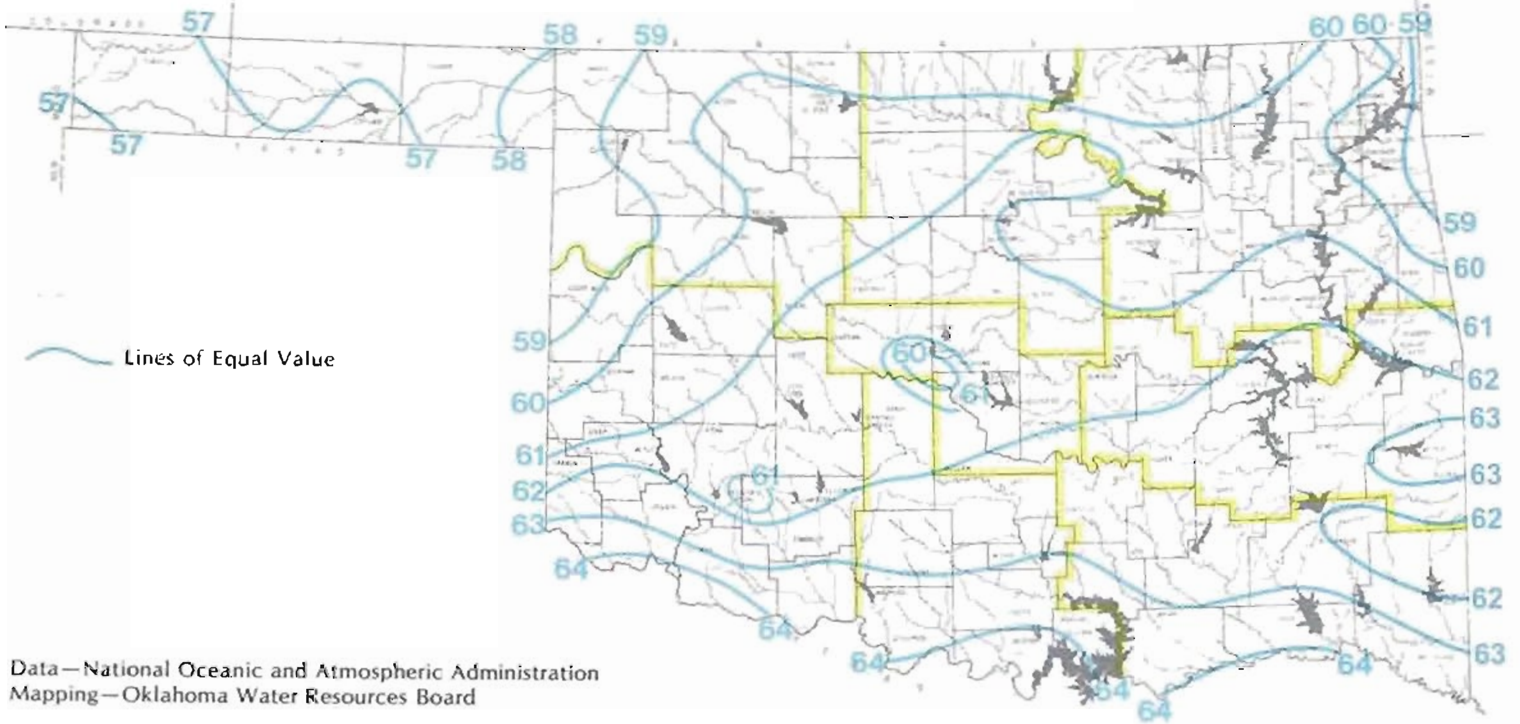


FIGURE 8 AVERAGE ANNUAL PRECIPITATION (In Inches)
Period 1931-1960

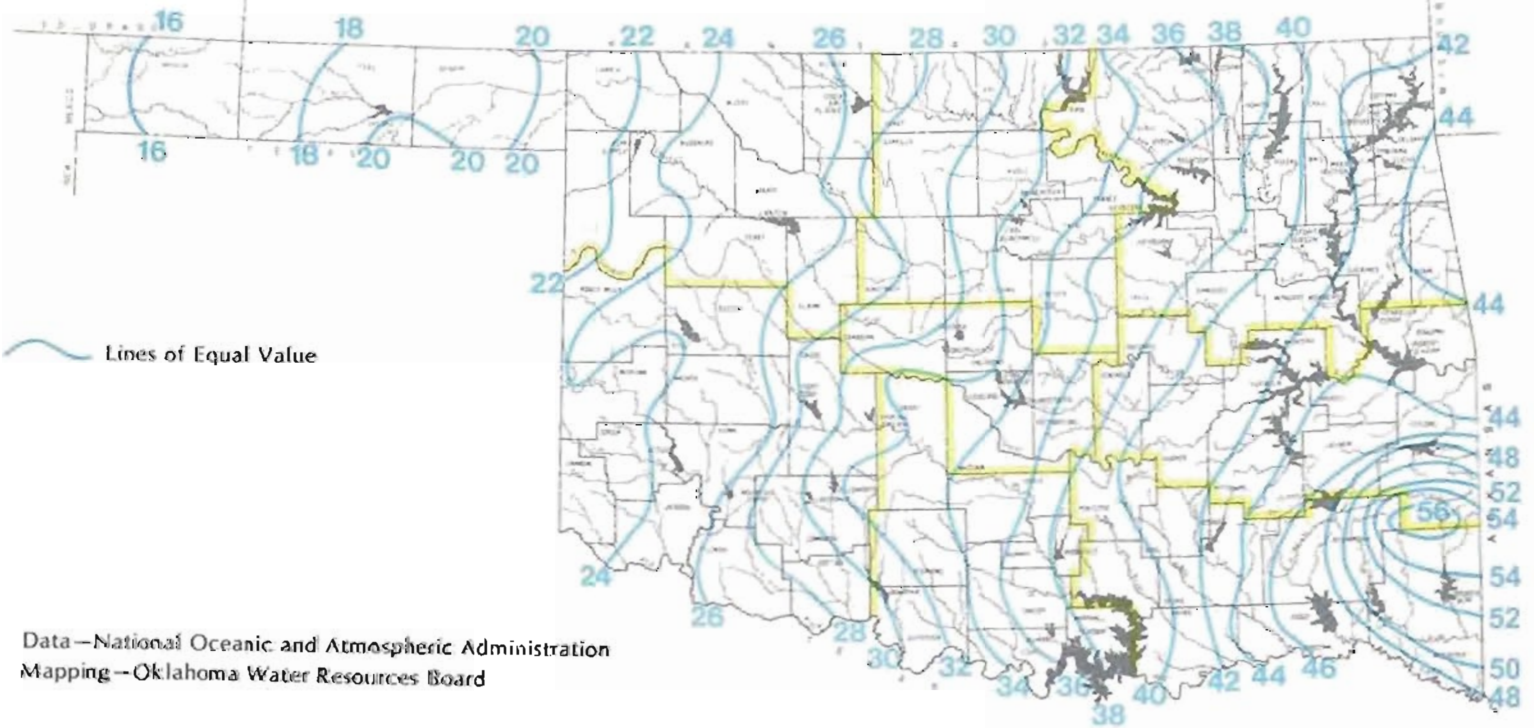
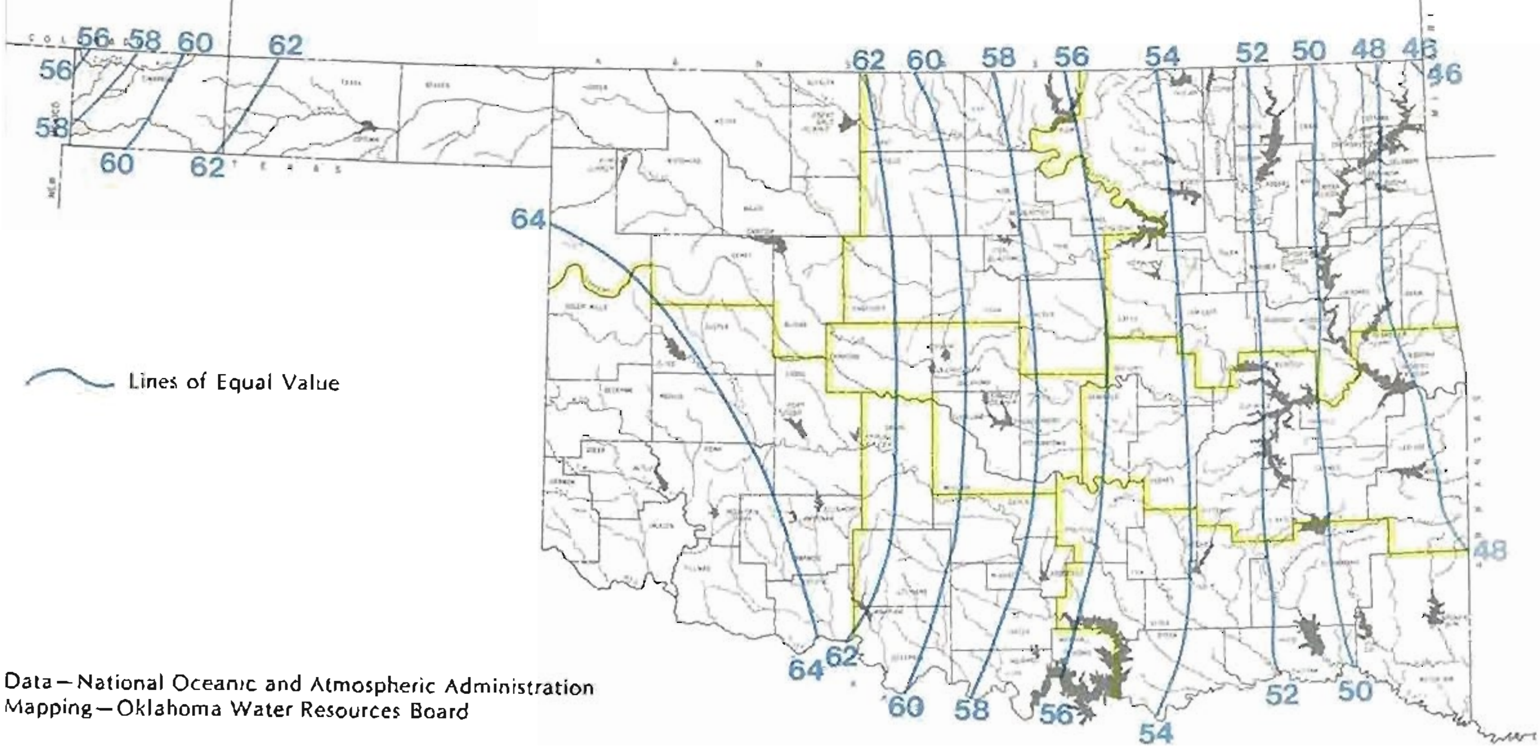


FIGURE 9 AVERAGE ANNUAL LAKE EVAPORATION (In Inches)
Period 1946-1955



Data—National Oceanic and Atmospheric Administration
Mapping—Oklahoma Water Resources Board

that cause Oklahoma to record the highest concentration of tornadoes in the world. May is usually the wettest month and rainfall decreases through the summer until fall, the second wettest season. January ranks as Oklahoma's driest month.

The geographical distribution of rainfall decreases sharply from east to west, ranging from an annual 56 inches measured in the southeastern corner to 15 inches in the western Panhandle. The contrast in annual rainfall is reflected in the officially recorded extremes of 6.53 inches at Regnier in Cimarron County in 1956 and 84.47 inches at Kiamichi Tower in LeFlore County in 1957. Snowfall across the state follows a general pattern of increasing from east to west. During the 1970's average snowfall accumulations ranged from six inches in the southeast to more than 19 inches in the southwest. However, despite recent heavy snowfalls in the west, winter precipitation accounts for only a small percentage of the area's annual total.

Mean annual temperature ranges from 64° F along the southern border to 60° F in the northeast, decreasing westward across the Panhandle to 57° F. High readings of 120° F have been reported at several stations, and the record low of -27° F occurred at Watts in 1930, and at Vinita in 1935. Oklahoma's average annual temperature pattern is shown in Figure 7 .

The length of the growing season, which is defined as the period between the average date of the last 32° temperature in the spring and the average date of the first 32° temperature in the fall, varies from 170 days in Cimarron County to 240 days in McCurtain County. East to west, along the northern border, the average date of the final spring freeze varies from April 5 to April 27; and in the south, from March 27 to April 5. The first fall freeze generally occurs between October 12 and October 27 in the north, and between November 5 and November 10 along the southern border, with the latest occurring in south central Oklahoma.

Annual lake evaporation averages 48 inches in the extreme east and 65 inches in the southwestern corner, as illustrated in Figure 9 . Evapotranspiration (loss of water into the air) and percolation (seepage of water into the ground) consume an average of 80 percent of the annual rainfall. Estimates of evaporation, precipitation, temperature, runoff and other variables are of great importance to planners in accurately determining reservoir yields. Careful, in-depth analyses of such data were employed in the development of the Oklahoma Comprehensive Water Plan.

SCENIC AND RECREATIONAL AREAS

Oklahoma's magnificent lakes, extensive state park system and privately developed recreational areas lure visitors from across the United States. There are 30 state parks and 23 recreational areas throughout the state under the supervision of the Oklahoma Tourism and Recreation Department. They offer camping facilities, entertainment, lodging and a variety of other recreational and social activities. South central Oklahoma's Chickasaw National Recreation Area at Sulphur is a popular attraction, and Grand Lake in the northeast has been extensively developed by private interests. Grand Lake's wooded hills, scenic lake waters and luxurious vacation homes distinguish it in the Southwest.

The state boasts a panorama of scenery such as the Talimena Skyline Drive in the southeast and the Black Mesa region of the Panhandle. Southwestern Oklahoma's Wichita Mountain Wildlife Refuge is one of only four national refuges for buffalo in the nation, grazing nearly 1,000 of this one time almost extinct species. The Wichitas and Arbuckles are the oldest mountains in Oklahoma, formed about the same time as the Appalachians. Mount Scott in the Wichitas is the state's best known peak, but Rich Mountain in the Ouachitas is the highest, rising 2,900 feet above southeastern Oklahoma's plain.

Oklahoma offers the sportsman excellent hunting and fishing with an abundance of lakes and rivers stocked with a wide variety of fresh water fish. Hunting for small game is superb throughout the state, and most areas offer whitetail deer. The dry, open northwest offers the sportsman mule deer and antelope as well. There are many public hunting areas and wildlife refuges where unique species of animals are preserved and enjoyed by campers, naturalists and tourists.

Areas across the state possess unique environmental habitats supporting a wide variety of sport fish, large and small game and waterfowl. Oklahoma is a sportsman's paradise for hunting and fishing, making this form of recreation a big business in terms of revenue. These outdoor activities add millions of dollars each year to the local and state economy in the form of licensing fees, fishing and hunting equipment, lodging expenses and retail sales.

Fishing water is plentiful, as evidenced by 663,000 acres of major reservoirs, 450,000 acres of farm ponds, approximately 23,000 miles of streams, and 17 lakes owned and managed by the Oklahoma Department of Wildlife Conservation. Oklahoma ranks third in the nation in fishable fresh waters. Within these waters sportsmen fish for native species of largemouth bass, crappie, channel catfish, white bass, sunfish, flathead catfish, sauger, paddlefish, spotted bass and smallmouth bass, as well as striped bass, walleye, northern pike and Florida bass that have been introduced to Oklahoma waters to provide even greater sport fishing opportunities.

The State Wildlife Conservation Department's fish hatcheries located at Holdenville, Durant, Medicine Park and Byron provide fish for planting, restocking and research. Annual stocking exceeds 25 million fish of 16 species, with the number of species varying each year to reflect needs and the requests for research, management and pond programs.

Oklahoma's abundance of large and small game provides boundless challenge to resident hunters and out-of-state adventurers. Whitetail deer are the most abundant big game animals, and are legal game in all 77 counties. Mule deer inhabit the Panhandle and extreme northwestern counties in limited numbers. Elk are confined mainly to refuge areas in the east and southwest. Antelope are native to the Panhandle, but are temporarily off limits to allow herd expansion.

Bobwhite quail, found in central and western prairie areas along field edges and shelter belts, are the most popular game birds in Oklahoma. Mourning doves are present in generous numbers across the state, while pheasants inhabit the Panhandle and northwest. Rio Grande turkeys abound throughout the western two-thirds of the state, while where about 10,000 birds are harvested annually. Another variety of wild turkey, smaller than the Rio Grand turkey, is being successfully introduced in eastern Oklahoma. Squirrel and rabbit are plentiful throughout Oklahoma, but are most abundant in the eastern half.

Ducks, geese and sandhill cranes offer numerous opportunities for waterfowl hunters. Because the state lies on the Central Flyway extending form Canada to Mexico, about a quarter of a million ducks migrate through Oklahoma annually. The major reservoirs and Arkansas River Navigation System in the east and smaller lakes, ponds and rivers of the west provide excellent hunting. Mallards are the most abundant species, with pintails, gadwalls, widgeon, teal and divers also plentiful. Canada geese are abundant statewide, while snows and blues are found mainly in the east. The best hunting is generally in wheat fields near the Great Plains Wildlife Refuge in the northwest, and in fields surrounding Tishomingo National Wildlife Refuge in the southeast. Sandhill cranes offer good hunting in the southwest along the Red River in Jackson and Tillman Counties.

Eleven wildlife species, officially listed by the federal government as "endangered", are believed to exist in Oklahoma. These species (seven birds, three mammals and one reptile) face the immediate threat of extinction. Despite the protection afforded endangered wildlife by state and federal law, loss of habitat, pesticide poisoning, certain forestry practices and illegal shooting are applying dangerous pressures to their existence.

Oklahoma's endangered species include the gray bat, black-footed ferret, Indiana bat, bald eagle, whooping crane, Ozark big-eared bat, red-cockaded woodpecker, Bachman's warbler, American peregrine falcon and American alligator. Although not yet officially listed as endangered, one other species in Oklahoma, the leopard darter, is threatened with extinction, if present trends continue.

WETLANDS

Wetlands are areas requiring a high soil moisture content or occasional inundation, and that land adjacent to or dependent on a body of water. The Soil Conservation Service estimates there are 53,000 acres of wetlands in Oklahoma, occurring along the flood plains of major streams and supporting countless varieties of fish, wildlife and plants.

Most of these wetland areas have been altered drastically by clearing for agricultural, residential and industrial development or inundated by water development pro-

FIGURE 10 OKLAHOMA POPULATION PROJECTIONS

YEAR / PLANNING REGION	1970[1]	1977[2]	1980	1990	2000	2010	2020	2030	2040
Southeast	130,954	144,000	160,700	181,000	197,800	212,700	227,300	239,700	250,100
Central	699,092	768,500	886,900	1,059,100	1,193,800	1,301,900	1,397,500	1,478,300	1,550,500
South Central	158,592	180,500	192,700	219,600	240,000	258,600	276,200	291,600	303,900
Southwest	268,369	284,500	286,600	306,100	325,900	343,200	360,900	377,300	391,800
East Central	172,734	190,600	191,800	208,600	224,900	240,300	255,700	269,000	280,300
Northeast	796,733	877,800	907,900	1,030,900	1,168,900	1,304,900	1,435,100	1,557,400	1,664,200
North Central	236,270	262,800	269,200	298,700	325,000	349,100	372,800	393,600	412,100
Northwest	96,719	102,000	105,800	112,700	119,600	123,500	127,400	131,300	135,200
STATE TOTAL	2,559,463	2,809,900	3,001,600	3,416,700	3,795,900	4,134,200	4,452,900	4,738,200	4,988,100

[1]U.S. Census of Population, 1970 Oklahoma P.C. (1)-338.

[2]Oklahoma Employment Security Commission estimate

jects. Few tracts remain undisturbed, the most extensive of these lying in the flood-plain of the Deep Fork River in Okmulgee, Creek and Okfuskee Counties.

ARCHEOLOGICAL AND HISTORICAL SITES

There are over 6,500 verified archeological sites located throughout Oklahoma's 77 counties, with Comanche, LeFlore, Cimarron, McCurtain and Osage Counties offering the greatest numbers. The locations of these counties indicate the wide distribution of archeological sites across the state.

There are 237 Oklahoma historical sites in 57 counties recorded in the National Register of Historical Places. These sites attract millions of visitors to Oklahoma each year, offering glimpses of Oklahoma's colorful history. Prominent among the attractions are the National Cowboy Hall of Fame in Oklahoma City, Tsa-La-Gi Cherokee Indian Village in Tahlequah, the Creek Council House in Okmulgee, the Philbrook Museum in Tulsa, the Will Rogers Museum in Claremore and the Quanah Parker Star House near Cache.

Coordination of historical and archeological site identification and preservation is accomplished at the state level with valuable assistance from local and regional societies. These local and regional societies assist by erecting historical markers, increasing public awareness, and by organizing local fund-raising efforts for site acquisition.

SOCIO-ECONOMIC CHARACTERISTICS

Oklahoma has experienced rapid social and economic growth in recent decades, evidenced by marked escalations in population, incomes, agricultural production and industrial development. Economists attribute such increases to the state's abundant natural resources (including available land and water) and its favorable labor and tax climates.

As part of the nation's "Sunbelt" region, Oklahoma can expect further development and growth, if it can continue to offer the water, land, energy and capital needed by new residents and industries without succumbing to adverse social and environmental impacts.

The rising and falling cycle of population figures over the past century is directly related to land. Prior to the 1920's the open lands of Oklahoma brought a steady in-migration, but the dust bowl days of the 1930's saw a drastic out-migration, as settlers abandoned their farms and homesteads to seek lands of greater promise. In-migration resumed in the 1960's, and the growth trend continued in the early 1970's. Today the Tulsa and Oklahoma City metropolitan areas account for almost half the state's population. Smaller cities –those over 2,000 –have maintained their populations or grown slightly, while rural areas and towns under 2,000 have shown delines in recent census estimates.

The population increased nearly 1,000 percent, rising from 258,657 to 2,811,000 between 1890 and 1977, at the same time showing a definite trend toward urban concentration. In 1910 only 19.2 percent of the population lived in cities or towns of 2,500 or more, but by 1940 this figure had increased to 37.6 percent, and in the 1970's had reached 68 percent.

Based on projections from the Oklahoma Employment Security Commission, the state's population is expected to reach 2.9 million by 1980; 3.7 million by 2000; and almost five million by the year 2040. Projections number the state's 2090 population in excess of six million, which is expected to be heavily concentrated in urban areas. See Figure 10.

Employment, Labor and Personal Income

Oklahoma has traditionally experienced a higher percentage of employed persons, or conversely, a lower unemployment rate, than the national average, an indication of the generally healthy condition of the state's economy and its relative immuity to short-term fluctuations in the national economy. In 1977 Oklahoma's average unemployment rate was five percent, with 1,166,000 of the total labor force of 1,227,000 employed. The national seasonally adjusted unemployment rate was seven percent during the same year.

Although Oklahoma boasts a favorable overall employment ratio, the distribution of employment indicates certain areas sustain much higher unemployment rates than others. Southeastern Oklahoma historically suffers high unemployment rates and northwestern Oklahoma nominal rates; a variation explained in part by the nature of the industry in each region. While the southeast's manufacturing and mining industries are sensitive to drop-offs in demand and register subsequent layoffs, the northwest's farmers are forced by their large personal capital investments to remain in agricultural pursuits despite market down trends. Population densities also influence the unemployment rate by determining the size of the labor force. Southeastern Oklahoma's higher concentration of people makes labor available in excess of demand, resulting in a higher unemployment rate than in the sparsely populated northwest, where the labor supply and demand are approximately balanced.

Covered employment is defined as the number of workers on the payroll for the period including the twelfth of each month, and who are employed by employers subject to the Oklahoma Employment Security Act. In 1977 the highest covered employment was recorded in wholesale and retail trade, which employed 231,696; manufacturing, which employed 163,902; and service industries, which employed 135,494. These three industries accounted for two-thirds of the average covered employment.

In terms of income, Oklahoma ranks somewhat below the national average of $7,026, with a 1977 per capita personal income of $6,269. Personal income is defined as current income received by residents from all sources, measured before the deduction of personal and income taxes, but after the deduction of personal contributions for Social Security, government retirement and other social insurance programs.

FIGURE 11 MAJOR INDUSTRIES

INDUSTRIAL GROUP	TOTAL NUMBER ESTABLISHMENTS	TOTAL NUMBER EMPLOYEES	AVERAGE WEEKLY EARNINGS
Lumber & Wood Products	146	3,687	174.46
Furniture & Fixtures	86	2,378	160.42
Stone, Clay & Glass	230	9,894	223.55
Primary Metal Industries	70	4,457	239.96
Fabricated Metal Products	438	19,737	227.67
Machinery, Except Electrical	511	25,652	231.25
Electrical Machinery	115	11,483	206.54
Food	319	16,183	199.52
Apparel	133	13,171	115.82
Printing & Publishing	565	9,463	181.19
Chemicals & Allied Products	100	2,814	270.48
Refining & Coal Products	36	8,807	292.86
Other Manufacturing	489	28,655	218.90
TOTAL	3,272	156,381	210.97

SOURCE: Research and Planning Division, Oklahoma Employment Security Commission, 1976.

Coinciding with the pattern of employment across the state, personal income is lower in the southeast and higher in metropolitan areas and the west. However, due to extensive employment in the oil and gas industry, Washington County in northeastern Oklahoma exhibits the highest 1977 per capita personal income at $9,972. Total personal income for the state in 1977 was $17,622,000,000.

Lower establishment costs, plentiful natural resources, an abundance of labor and lower living costs have attracted business and industry to Oklahoma, spurring rapid and highly diversified industrial growth in recent years. Today Oklahoma ranks thirty-second in the nation in industrial development.

In 1976 there were 3,272 major industries in Oklahoma with an annual payroll of over $1.7 billion. Wood and pulp manufacturing industries find bountiful supplies of water needed in processing, and vast oil and gas deposits lend themselves to all facets of energy production, as well as the manufacture of allied products.

Since Oklahoma is predominantly an agricultrual state, agribusiness firms have also migrated to the region, opening profitable markets in farm machinery, seed supplies and fertilizer products. Processing, packing and canning operations have also flourished in the state.

Agricultural Development

Since Land Run days, Oklahoma's climate, soil, water and available lands have attracted farmers and ranchers, and products of the soil in the form of cattle, grain and feed seed crops have made major contributions to the state's economy. In 1976 the state ranked second in the nation in winter wheat production, fifth in grain sorghum, sixth in peanuts for nuts, and sixth in cattle, achieving a total agricultural production value of almost $1.8 billion. The record for production value was established in 1973 with a figure of over $2.1 billion.

There were approximately 86,000 farms in Oklahoma in 1976, averaging 428 acres in size. The most recent complete farm census in 1974 indicated Oklahoma had 38,449 full owners of farms, 22,847 part owners of farms and 8,423 tenants on farms, with figures in all three categories down from previous censuses. These statistics support the trends in evidence throughout the western United States of (1) migration from farms to urban areas, and (2) increase in farm sizes in an attempt to lower unit costs through increased production to defray escalating costs of farm machinery.

Significant portions of the state's industrial economy have grown in response to agricultural development and are dependent upon it. These agribusinesses constitute a multibillion dollar contribution to the state's total economy and include canning and processing of foods and by-products; agricultural supplies, equipment and services; and transportaion and marketing services.

According to the Oklahoma State University Extension Service, irrigated agriculture is on the rise in Oklahoma. The slight decrease registered between 1975 and 1977 is attributed to greater precipitation, higher fuel costs and depressed crop prices, and is not considered indicative of a future trend. See Figure 13. In 1977, 895,802 acres were irrigated, almost 400,000 of them located in the Panhandle counties of Cimarron, Texas and Beaver. Wheat, grain sorghum and alfalfa were the top three irrigated crops. In addition to providing greater crop yields per acre and allowing crops to be grown in areas where they could not be grown under natural conditions, irrigation stimulates local economies by opening new markets for sprinkler systems, fertilizers and other related products.

FIGURE 12 GEOLOGIC TIME SCALE

GEOLOGIC ERA	GEOLOGIC PERIOD	BEGINNING (MILLION YEARS AGO)
Cenozoic	Quaternary	1
	Tertiary	70
Mesozoic	Cretaceous	135
	Jurassic	180
	Triassic	220
Paleozoic	Permian	270
	Pennsylvanian	320
	Missippian	350
	Devonian	400
	Silurian	430
	Ordovician	490
	Cambrian	600
Precambrian		4,500

GEOLOGY

Most of the rocks that outcrop in Oklahoma are of sedimentary origin, consolidated from sediments deposited during the Paleozoic era and covering about 75 percent of the state. Locally, some Paleozoic formations achieve a thickness of 40,000 feet. The oldest of these are the Precambrian granites and rhyolites formed 1.05 to 1.35 billion years ago. Precambrian and Cambrian igneous and metamorphic rocks underlie all of the state, and provide the "floor" upon which all younger rocks rest.

The three principal mountain belts -- southern Oklahoma's Ouachitas, Arbuckles and Wichitas – were formed by folding, faulting and

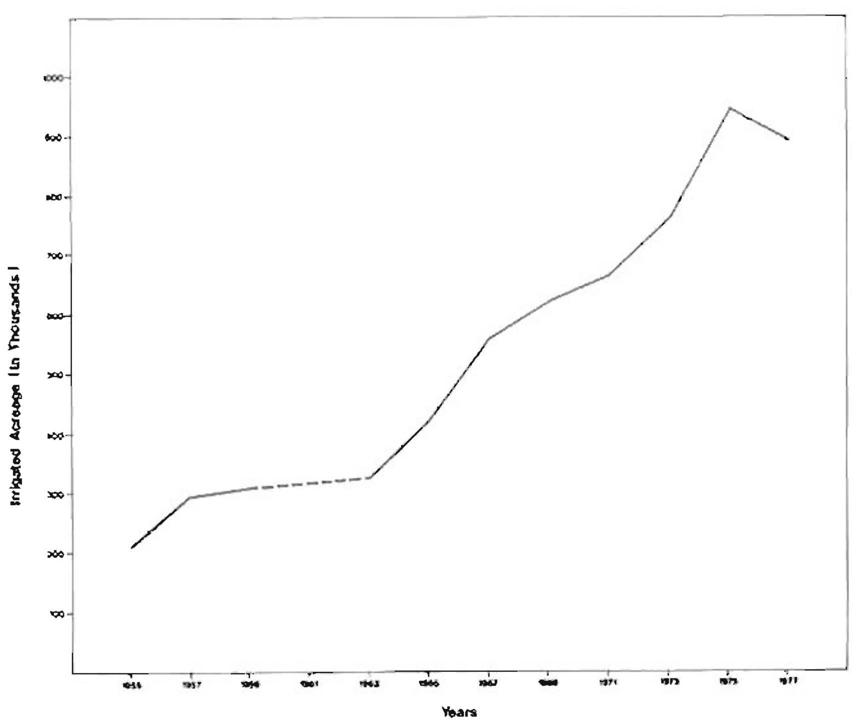
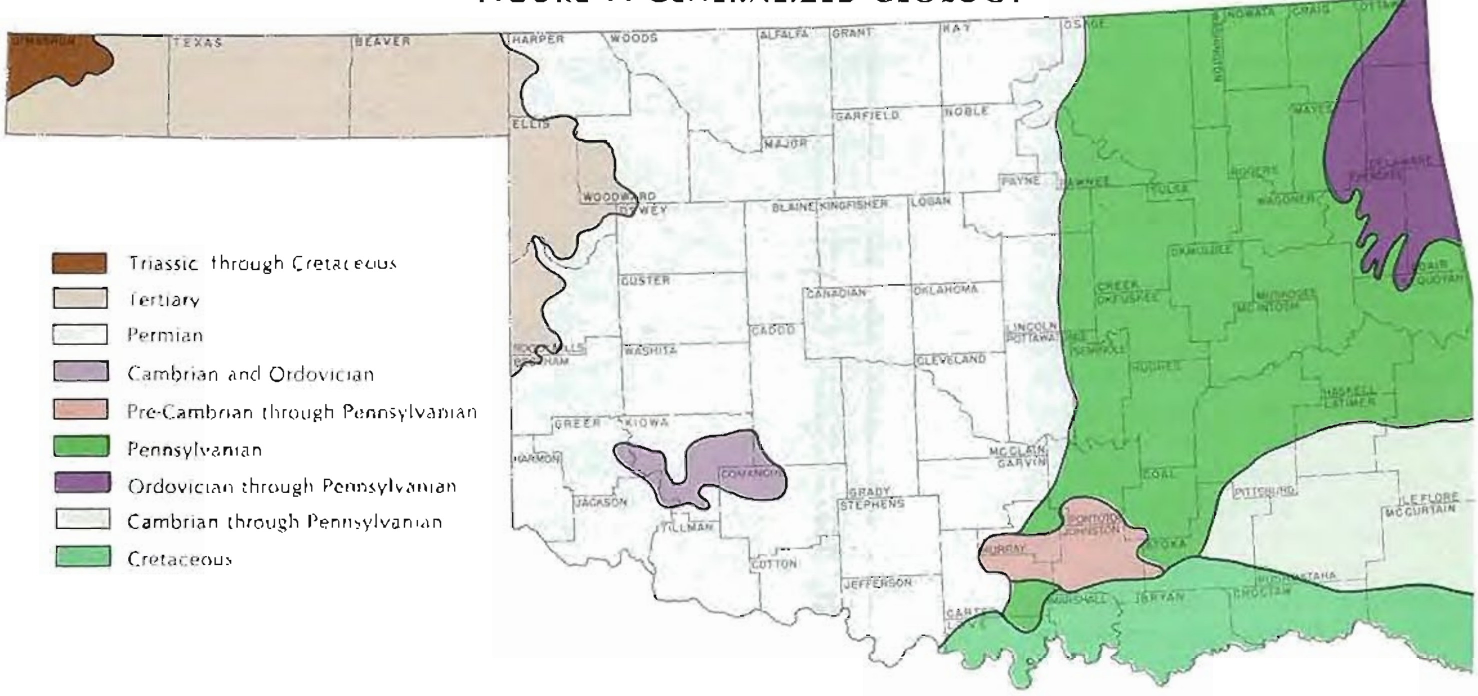


FIGURE 13 ACRES IRRIGATED IN OKLAHOMA

FIGURE 14 GENERALIZED GEOLOGY



uplift during the Pennsylvanian period. North of these mountain uplifts lie the deep Anadarko and Arkoma basins, and still farther north, the relatively undisturbed shelf areas of northern Oklahoma.

Nonmarine shales and sandstones characterize the Mesozoic sedimentary rocks of Oklahoma. Shallow seas covered southern and western Oklahoma during some of the era's Cretaceous period, and marine deposits resulted in limestone and shale.

Since the beginning of the Tertiary period, none of the state has been covered by sea water. Oklahoma's land surface sloped down to the east and southeast, and extensive deposits of Tertiary sand and gravel were washed in by large rivers flowing from the newly formed Rocky Mountains.

The Quaternary period through the present is characterized as a time of erosion. Rocks and loose sediment at the surface are being weathered to soil, then the soil particles are carried away to streams and rivers. In this way, hills and mountains are worn down, and the sediment is either carried to the sea or at least temporarily deposited on the banks and in the bottoms of rivers and lakes.

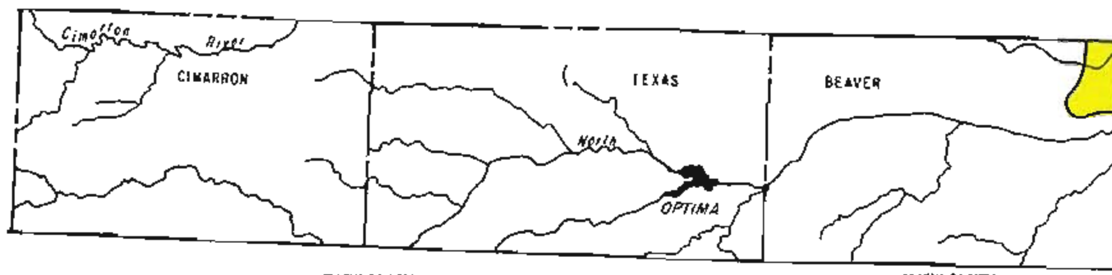
LAND RESOURCES

Oklahoma has a total area of 44,748,160 acres, with 43,762,176 land acres as of January 1978. Of this land area, 1,727,778 acres are classified as built-up and urban land; 14,488,295 acres as rangeland; 10,751,304 acres as cropland; 6,896,928 acres as pastureland; and 6,764,249 acres as forestland. There were 895,802 acres under irrigation in 1977, with most of the total lying in western Oklahoma.

The Federal Government owns 1,098,939 acres in the state, with

FIGURE 15 MAJOR AGRICULTURAL LAND USES
(In Acres)

PLANNING REGION	CROPLAND	PASTURELAND	FORESTLAND	RANGELAND	WATER 40 ACRES	WATER 40 ACRES	TOTAL
Southeast	163,363	1,636,516	2,132,679	626,655	103,055	19,016	4,618,284
Central	525,389	434,340	207,955	694,904	49,190	17,006	1,928,784
South Central	556,863	561,238	468,002	1,654,344	102,300	20,419	3,363,166
Southwest	3,047,122	310,223	241,446	2,503,917	117,385	66,909	6,287,002
East Central	175,350	1,299,333	1,901,975	707,831	176,900	20,212	4,281,601
Northeast	613,835	2,144,468	1,567,869	2,015,923	214,960	59,462	6,616,317
North Central	2,091,128	392,965	142,902	1,742,719	78,430	34,131	4,488,275
Northwest	3,578,254	117,845	101,421	4,542,202	143,764	33,324	8,516,810
STATE TOTAL	10,751,304	6,896,928	6,764,249	14,488,295	985,984	270,479	40,157,239



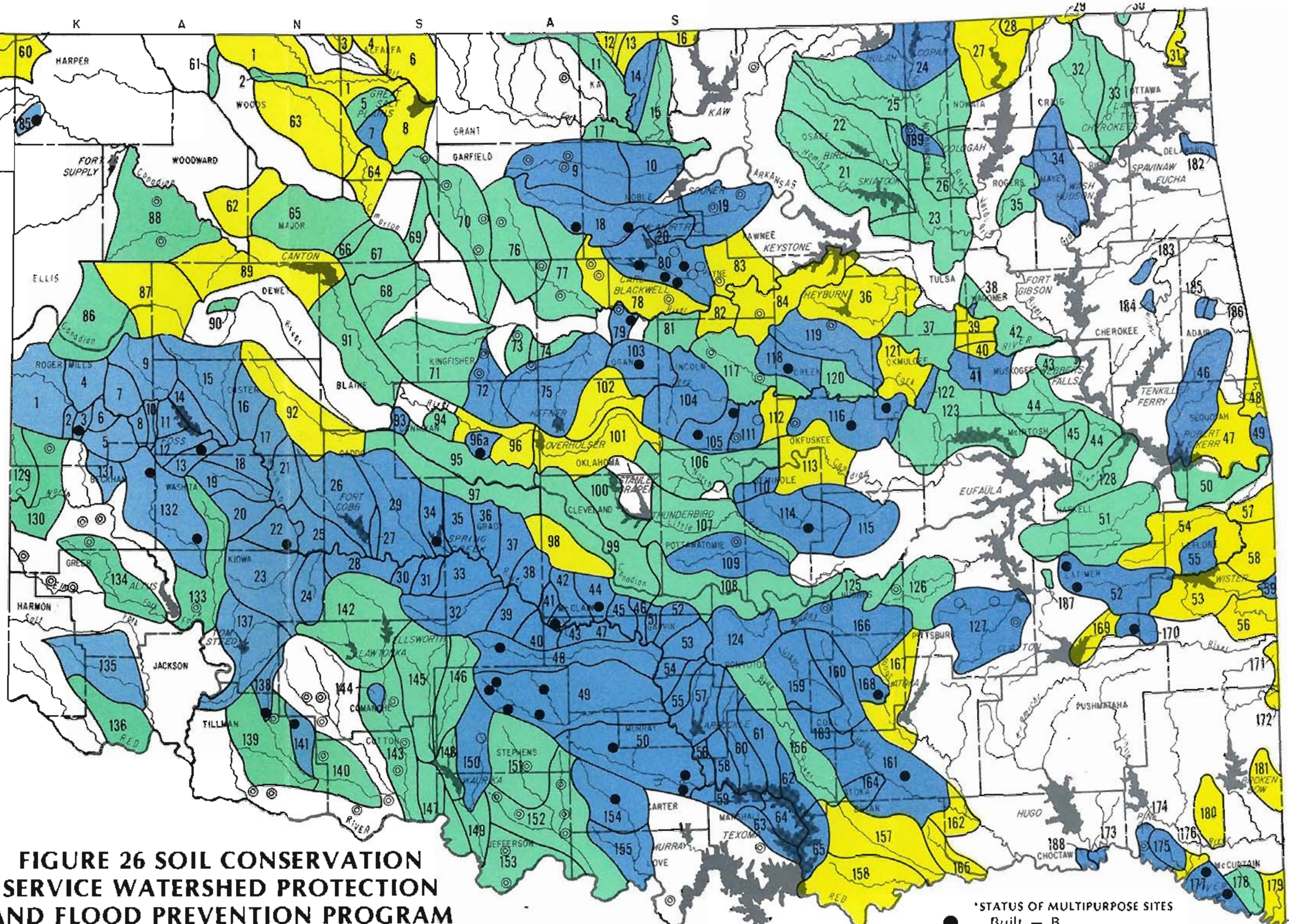


FIGURE 26 SOIL CONSERVATION SERVICE WATERSHED PROTECTION AND FLOOD PREVENTION PROGRAM

WATERSHED No.	Name	Drainage Area (Acres)	STATUS OF SITES Planned	Completed or Under Construction	Multi-Purpose Sites*
	ARKANSAS RIVER BASIN				
1	Salt Fork Arkansas River	200,710	0	0	
2	Turkey Boggy Creek	37,900	0	0	
3	Little Mule Creek	18,349	0	0	
4	Medicine Lodge River	49,574	0	0	
5	Cottonwood Canyon	36,000	0	0	
6	Little Sandy Creek	99,424	0	0	
7	Lambert Creek	8,000	2	2	
8	Clay Creek	126,810	0	0	
9	Upper Red Rock Creek	197,376	56	36	1-Pt
10	Lower Red Rock Creek	116,582	26	7	
11	Stink Creek	119,629	0	0	
12	Shoo Fly Creek	30,861	0	0	
13	Bitter Creek	93,820	0	0	
14	Lost-Duck	55,040	12	0	
15	Bois D'Arc-Cowskin	80,000	0	0	
16	Chilocco Creek	24,826	0	0	
17	Birds Nest Creek	24,500	0	0	
18	Upper Black Bear Creek	241,546	76	69	2-B
19	Lower Black Bear Creek	157,861	26	11	3(1-P, 2-Pt)
20	Long Branch	28,160	11	11	
21	Hominy Creek	248,636	0	0	
22	Upper Bird Creek	248,790	0	0	
23	Lower Bird Creek	244,050	0	0	
24	Cotton-Coon-Mission Creeks	198,170	15	5	
25	Sand-Hogshooter Creeks	242,560	0	0	
26	Lower Caney River	152,940	0	0	
27	Upper Verdigris River	170,214	0	0	
28	Snow Creek	21,130	0	0	
29	Hackberry Creek	2,701	0	0	
30	Fly Creek	5,811	0	0	
31	Spring River Laterals	30,784	0	0	
32	Upper Big Cabin	141,544	0	0	
33	Lower Big Cabin	146,944	0	0	
34	Pryor Creek	180,000	6	2	
35	Dog Creek	81,933	0	0	
36	Polecat Creek	218,752	0	0	
37	Duck and Snake Creeks	115,540	0	0	
38	Kadashan Bottom	6,000	5	1	
39	Haskell Laterals	48,864	0	0	
40	Ash Creek	27,149	0	0	
41	Cane Creek	101,755	28	18	
42	Broken Arrow-Cedar Creeks	86,181	0	0	
43	Cody Creek	33,130	0	0	
44	Dirty Creek	215,000	0	0	
45	George Fork Creek	38,920	0	0	
46	Sallisaw Creek	185,280	14	14	
47	Big Skin Bayou-Camp Creek	116,474	0	0	
48	Lee Creek	44,146	0	0	
49	Garrison Creek	21,521	4	0	
50	Cache-Coal Creeks	76,166	0	0	
51	Sans Bois Creek	205,000	0	0	
52	Fourche Maline	175,360	14	14	2-B
53	Holston-Reichert Cons. Dist.	97,792	0	0	
54	Brazil Creek	152,100	0	0	
55	Caston-Mountain	46,136	5	5	
56	Black Fork Creek	133,414	0	0	
57	James Fork Creek	138,975	0	0	
58	Combined Creek	118,272	0	0	
59	Poteau River	18,400	0	0	
60	Old Settlers Ditch	90,362	0	0	
61	Houston Creek	18,000	0	0	
62	Main Creek	72,250	0	0	
63	Eagle Chief Creek	239,757	0	0	
64	Lower Eagle Chief Creek	89,107	0	0	
65	Greever Creek	200,045	0	0	
66	Sand	15,000	0	0	
67	Sand Deep Creek	107,104	0	0	
68	Salt Creek	121,661	0	0	
69	Hoyle	36,768	0	0	
70	Turkey Creek	239,000	12	0	4-Pt
71	Kingfisher Creek	215,000	0	0	
72	Uncle John's Creek	97,970	14	12	2-Pt
73	Campbell	41,420	0	0	1-Pt
74	Gar-Pawnee Creeks	38,150	0	0	
75	Cottonwood Creek	242,470	36	36	1-Pt
76	Upper Skeleton Creek	247,800	0	0	2-Pt
77	Lower Skeleton Creek	154,200	0	0	1-Pt
78	Beaver Creek	159,187	0	0	1-Pt
79	Fitzgerald and Soldier Creeks	18,700	5	4	2(1-B, 1-Pt)
80	Stillwater Creek	177,216	54	26	7(4-B, 3-P)
81	Perkins Laterals	61,800	0	0	
82	Big Creek	48,493	0	0	1-Pt
83	Council-Salt Creeks	113,382	0	0	1-Pt
84	Chilton Laterals	187,494	0	0	
85	Paint Creek	15,939	1	1	1-B
86	Ant Hill Laterals	185,581	0	0	
87	Turkey-Gyp Creeks	190,426	0	0	2-Pt
88	Indian-Persimmon-Sand Creeks	282,355	0	0	
89	Bent Creek	256,397	0	0	
90	J.V. Flats	4,870	0	0	
91	Canton Laterals	235,482	0	0	
92	Deer Creek	219,648	0	0	
93	Canyon View	8,130	4	4	
94	Six Mile Creek	20,160	0	0	
95	Union City Laterals	112,512	0	0	
96	Shell-Purcell Creek	83,000	0	0	
96a	Four Mile Creek	15,360	1	1	1-B
97	Minco Laterals	174,931	0	0	
98	Walnut Creek	124,416	0	0	
99	Buckhead-Chouteau Lateral	226,016	0	0	
100	Upper Little River	77,500	0	0	
101	City Lateral	213,504	0	0	
102	Upper Deep Fork	130,560	0	0	
103	Bear-Fall-Coon Creeks	120,960	31	31	1-B
104	Kickapoo Nations	165,300	20	0	1-P
105	Quapaw Creek	100,198	44	37	2-B
106	Shan-Rock Creeks	207,782	0	0	
107	Central Little River	220,168	0	0	
108	Ash Lateral	270,861	0	0	
109	Salt Creek	152,000	49	34	1-Pt
110	Pott-Sem-Turkey Creeks	34,560	11	0	
111	Robinson Creek	40,230	11	0	2 (1-P, 1-Pt)
112	Pettiquah-Deer Creeks	47,840	0	0	
113	Gar-Snake-Sand Creeks	160,704	0	0	
114	Big Wewoka Creek	172,525	41	41	1-B
115	Little Wewoka Creek	122,445	16	16	
116	Okfuskee Co. Tributaries	201,575	35	23	3(2-B, 1-Pt)
117	Bell Cow-Dry Creek	162,080	0	0	2-Pt
118	Salt-Camp Creeks	73,030	25	1	1-B
119	Little Deep Fork Creek	167,488	56	56	1-Pt
120	East-West Sandy Creeks	53,888	0	0	
121	Checkerboard Creek	95,296	0	0	
122	Okmulgee Creek	14,490	7	2	
123	Lower Deep Fork	251,910	0	0	
124	Sandy Creek	147,243	33	27	
125	Atwood-Calvin Tributaries	72,000	0	0	
126	Coal Creek	132,000	0	0	1-Pt
127	Brushy-Peaceable Creeks	213,686	46	6	3(2-P, 1-Pt)
128	Stigler Laterals	117,402	0	0	
	RED RIVER BASIN				
129	Lower Sweetwater Creek	137,911	0	0	
130	North Fork Red River	140,974	0	0	1-Pt
131	Timber Creek	41,700	7	7	
132	Upper Elk Creek	234,000	47	33	2-B
133	Lower Elk Creek	163,923	0	0	1-Pt
134	Lower Elm Fork	164,000	0	0	1-Pt
135	Tri-County Turkey Creek	196,400	35	37	
136	Gypsum Creek	95,610	0	0	
137	Otter Creek	177,920	4	0	
138	Deep Red Run and Coffin Crs	50,600	2	2	1-B
139	Middle Deep Red Run	186,688	0	0	1-Pt
140	Lower Deep Red Run	112,627	0	0	1-Pt
141	Jack Creek	45,184	11	10	1-B
142	Upper East Cache Creek	287,002	0	0	
143	Lower East Cache Creek	245,139	0	0	3-Pt
144	Squaw Creek	7,940	0	0	
145	Big Beaver Creek	177,000	0	0	
146	Little Beaver Creek	124,800	0	0	
147	Whiskey Creek	45,240	0	0	
148	Lower Beaver Cr. above Waurika Dam	60,224	0	0	
149	Lower Beaver Cr. below Waurika Dam	65,517	0	0	
150	Cow Creek	122,880	47	47	1-P
151	Upper Mud Creek	181,318	0	0	1-Pt
152	Lower Mud Creek	288,840	0	0	5-Pt
153	Fleetwood and Red River	143,040	0	0	2-Pt
154	Upper Bayou	119,680	22	5	1-B
155	Lower Bayou	95,488	20	9	
156	Upper Blue River	203,100	74	0	
157	Lower Blue River	236,032	0	0	
158	Island Bayou	213,576	0	0	
159	Upper Clear Boggy Creek	162,240	54	46	
160	Leader-Middle Clear Boggy Cr	107,960	43	33	
161	Lower Clear Boggy Creek	240,301	31	11	1-B
162	South Boswell Laterals	45,855	0	0	
163	Delaware Creek	50,016	13	13	
164	Caney Creek	30,541	15	13	
165	(No Name)	72,357	0	0	
166	Upper Muddy Boggy Creek	198,000	36	0	1-Pt
167	Middle Muddy Boggy Creek	149,000	0	0	1-Pt
168	Caney-Coon Creeks	23,571	3	1	1-B
169	Buffalo Creek	49,000	0	0	1-B
170	Rock Creek	37,997	4	4	1-B
171	(No Name)	38,848	0	0	
172	Cove-Hatfield	22,500	0	0	
173	Frogville	9,173	2	2	
174	McKinney-Buzzard Creek	13,865	1	0	1-Pt
175	Whitegrass-Waterhole Creeks	39,575	0	0	
176	Vokichita Creek	23,654	0	0	
177	Waterfall-Gilford Creeks	43,410	12	9	2-B
178	Norwood Creek	41,600	0	0	
179	Walnut Bayou	42,750	0	0	
180	Lukfata Creek	34,458	0	0	
181	(No Name)	40,177	0	0	
	R C & D PROJECTS				
182	Whitewater CH-1	19,738	2	2	
183	Fourteen Mile CH-2	1,181	2	2	
184	Town Branch CH-3	4,640	2	0	
185	Scraper Hollow CH-4	5,338	2	2	
186	England Hollow CH-5	4,960	2	0	
187	Boiling Springs OM-1	3,184	1	1	
188	Goodwater Creek OM-2	7,898	1	0	

CH-Cherokee Hills RC&D
OM-Ouachita Mtns. RC&D

WATERSHED No.	Name	Drainage Area (Acres)	STATUS OF SITES Planned	Completed or Under Construction	Multi-Purpose Sites*
	PILOT PROJECT				
189	Double Creek	30,272	6	6	1-Pt
	WASHITA RIVER				
1	Upper Washita River	471,730	35	35	
2	Broken Leg Creek	10,523	3	3	
3	Sergeant Major Creek	19,684	6	5	1-B
4	Dead Indian-Wildhorse Creek	64,867	11	11	
5	Sandstone Creek	65,013	24	24	
6	Beaver Dam Creek	27,620	6	6	
7	Nine Mile Creek	34,315	18	16	
8	Big Kiowa Creek	25,922	9	6	
9	Quartermaster Creek	123,377	36	36	
10	Whiteshield Creek	17,384	20	19	
11	Panther Creek	47,216	6	6	
12	Soldier Creek	44,748	9	9	
13	Turkey Creek	47,320	12	12	1-B
14	Butler Laterals (Reach II)	47,114	6	6	
15	Barnitz Creek	178,674	69	69	
16	Beaver Creek	36,605	16	15	
17	Bear Creek	53,605	10	10	
18	South Clinton Laterals	30,817	6	6	
19	Boggy Creek	74,043	36	36	
20	Cavalry Creek	69,952	30	30	
21	Gyp Creek (Reach II)	71,828	2	1	
22	Oak Creek	46,394	11	11	1-B
23	Rainy Mountain Creek	209,959	43	37	
24	Saddle Mountain Creek	72,420	7	7	
25	Cowden Laterals (Reach II)	81,884	14	10	
26	Cobb Creek	207,360	10	10	
27	Cobb (Fast Runner) Creek	7,735	10	10	
28	Ft. Cobb Laterals (Reach III)	77,520	13	6	
29	Sugar Creek	189,076	42	42	
30	Tonkawa Creek	30,640	12	12	
31	Delaware Creek	36,879	3	2	
32	Little Washita River	150,808	50	43	
33	Line Creek	50,516	0	0	
34	Spring Creek	53,492	1	1	1-B
35	Finnie Creek	54,521	12	0	
36	Salt Creek	63,265	0	0	
37	Bitter Creek	73,243	27	18	
38	Winter Creek	61,722	25	20	
39	Roaring Creek	67,995	37	32	
40	Round Creek	46,702	9	4	
41	Colbert Creek	14,812	3	3	
42	Criner Creek	43,480	27	27	
43	Bear-Hybarger Creek	23,557	11	11	1-B
44	Finn Creek	58,036	36	34	1-B
45	Wayne Creek	20,576	7	7	
46	Owl Creek	14,345	15	15	
47	Maysville Creek Laterals	44,234	27	21	
48	Rush Creek	191,557	49	47	1-B
49	Wildhorse Creek, Upr & Lwr	427,943	116	99	5-B
50	Caddo Creek	262,349	29	28	3-B
51	Washington Creek	17,468	3	0	
52	Peavine Creek	38,645	10	10	
53	Cherokee Sandy Creek	46,291	21	15	
54	Kickapoo Sandy Creek	41,662	22	20	
55	Chigley Sandy Creek	39,349	14	14	
56	Big Canyon Laterals	24,609	0	0	
57	Rock Creek	109,043	17	17	
58	Oil Creek	40,762	0	0	
59	Mansville Laterals	56,064	0	0	
60	Mill Creek	77,735	18	18	
61	Pennington Creek	14,805	3	1	
62	Big Sandy Creek	40,119	0	0	
63	Glasses Creek, Big and Little	47,733	0	0	
64	West Laterals to Texoma	37,033	0	0	
65	East Laterals to Texoma	38,067	0	0	

STATUS OF WATERSHEDS

- Complete or Under Construction
- Planned
- Potential

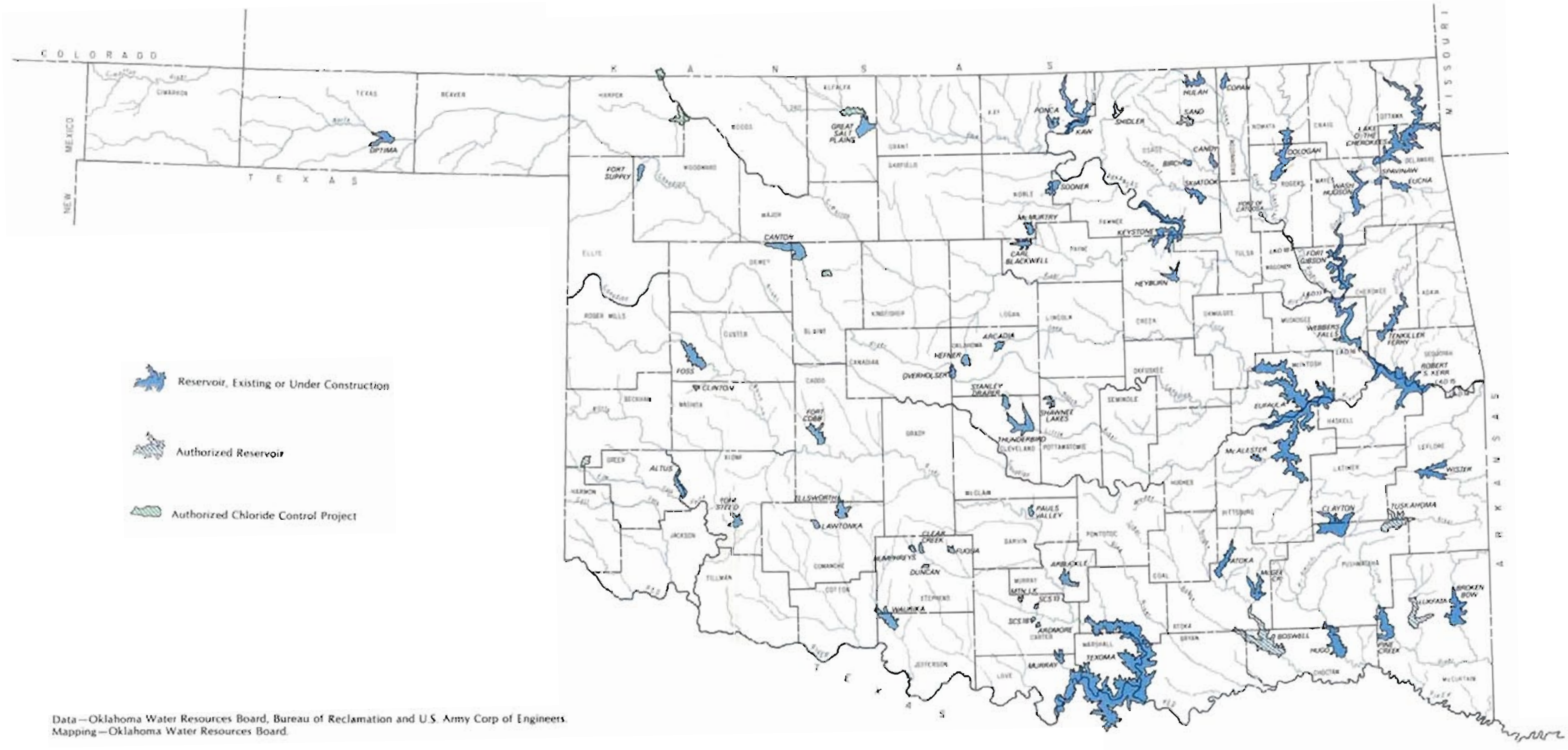
*STATUS OF MULTIPURPOSE SITES

- Built — B
- Planned — P
- Potential — Pt.

Indicates number of sites only, not exact location

*Other potential multipurpose sites which appear on map are not in a designated watershed and therefore are not listed in this legend.

Data—Soil Conservation Service
Drafting—Oklahoma Water Resources Board



Data—Oklahoma Water Resources Board, Bureau of Reclamation and U.S. Army Corp of Engineers.
Mapping—Oklahoma Water Resources Board.

FIGURE 25 WATER RESOURCES DEVELOPMENT

FIGURE 16 OKLAHOMA LAND INVENTORY SUMMARY
(In Acres)

PLANNING REGION	TOTAL AREA	WATER AREA[1]	URBAN AREA	AREA IN ROADS AND RAILROADS	FEDERAL AND STATE LAND AREA[2]	PRIVATELY OWNED RURAL LAND
Southeast	5,068,160	103,055	62,625	48,786	199,838	4,653,856
Central	2,268,160	49,190	207,342	32,818	73,553	1,905,257
South Central	3,711,360	102,300	59,226	46,675	83,691	3,419,468
Southwest	7,043,840	117,385	90,155	160,811	336,734	6,338,755
East Central	5,010,560	176,900	84,819	66,599	310,215	4,372,027
Northeast	7,548,160	214,960	326,658	110,906	290,312	6,605,324
North Central	4,920,960	78,430	97,849	129,053	213,127	4,402,501
Northwest	9,176,960	143,764	38,926	164,530	510,466	8,319,274
STATE TOTAL	44,748,160	985,984	967,600	760,178	2,017,936	40,016,462

[1]Includes bodies of water greater than 40 acres in size and riverbeds more than one-eighth mile wide

[2]Includes only state and federal owned lands. Does not include leased lands.

almost half owned by the Corps of Engineers through its major water reservoir projects. The State of Oklahoma holds 918,997 acres, with over 80 percent of it in school lands. Figure 16 shows present land use in the state as determined by the Soil Conservation service in its Oklahoma Land Inventory of January 1978.

The principal agricultural industry in the state is beef production, followed by wheat and dairy cattle. This predominance of beef production prevails throughout western, central and east central Oklahoma, but the northeast and southeast show more diversified production including barley and oats, sorghum, soybeans, corn and hay. In the northeast soybean production has doubled every 10 years since 1940, while east central and south central Oklahoma boast thriving commercial timber and wood products industries.

The first detailed soil surveys were conducted in Oklahoma County and a small area near Tishomingo in 1905. Soil survey maps and reports are available for 69 counties, with reconnaissance level work in progress for the remaining eight counties.

Oklahoma soil surveys are made according to the "series concept" of classification. A series is a group of soils with similar profile characteristics and arrangements, excluding surface texture.

Soil associations occur together naturally in a defined proportional pattern on a unique type of landscape. These associations are comprised of several series whose charactristics, including climate, parent materials and natural vegetation, are similar. Figure 17 illustrates existing soil associations and series with each association.

Broad differences exist in state soils. In the eastern part soils were developed under humid conditions where leaching is intense. These soils are low in phosphorus, lack adequate potassium and range from moderately to strongly acid. The vast western prairies, developed under lower rainfall levels, exhibit a light red color and are less leached than eastern soils. They are moderately acid, but low in phosphorus and nitrogen. Soils in the northwest region contain great amounts of lime and are neutral to alkaline at the surface, with calcium carbonate accumulations found at shallow depths. Nitrogen levels are low, but are not usually a limiting factor. Wind erosion is often the most serious soil management and crop production problem.

MINERAL RESOURCES

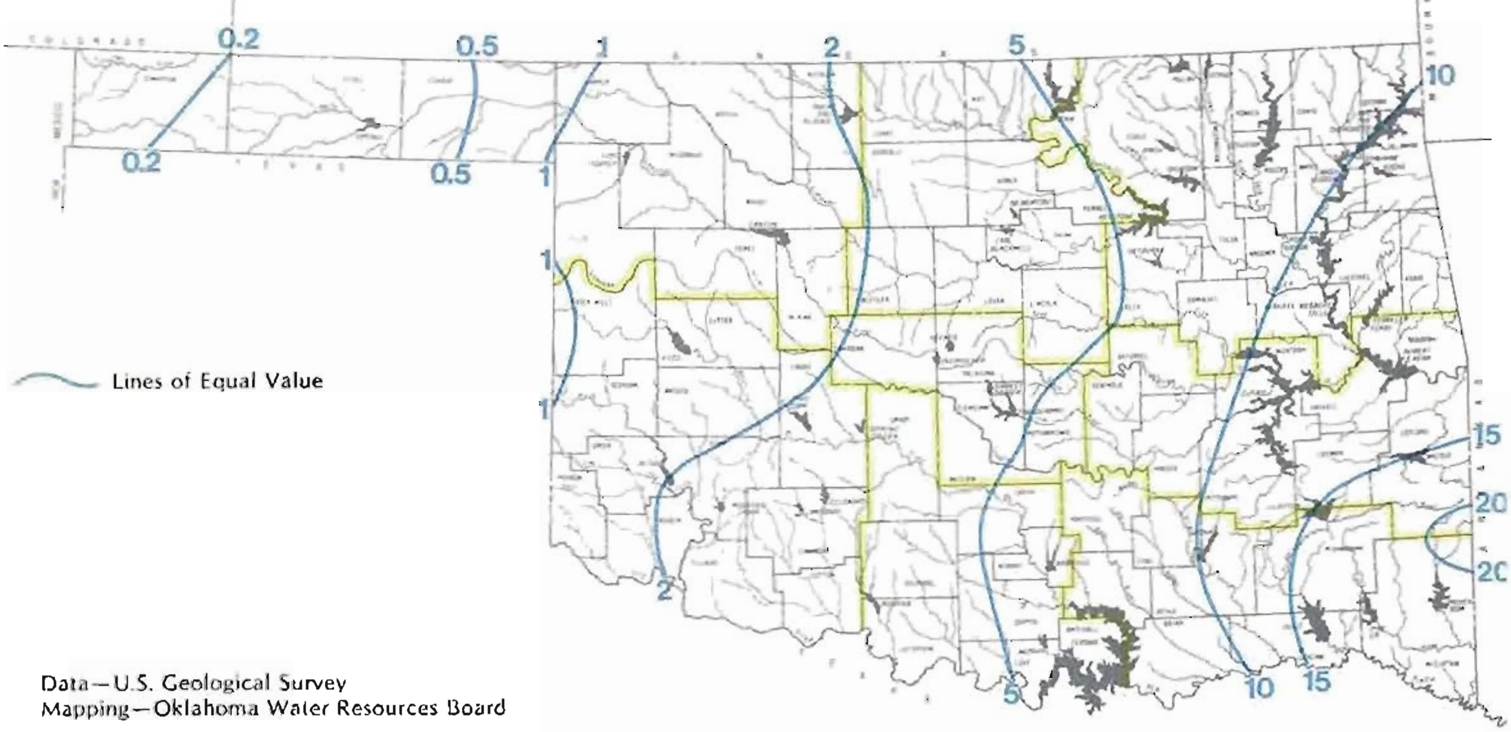
The primary mineral resource of Oklahoma is oil and gas, with a number of other minerals produced on a smaller scale. The total value of mineral production in Oklahoma, rising rapidly to reflect the worldwide escalation of oil prices, reached a record $3.5 billion in 1977, compared to $1.3 billion in 1973. About 96 percent of the 1977 value was derived from the production of fossil fuels, while produced metal and nonmetallic minerals accounted for the remaining four percent.

The tremendous gains in value of produced minerals are somewhat misleading and must be analyzed in terms of the production and value of crude oil and natural gas. According to the Bureau of Mines publication, "Minerals in the Economy of Oklahoma," the unit value of Oklahoma crude petroleum has increased approximately 162 percent since 1973, while annual production of crude oil has declined 29 percent. Unit value of natural gas was up 321 percent in 1977 over that of 1973, but production rose only three percent in 1977. Thus, as a result of the increase in crude oil and natural gas values, the total value of all mineral production is highly inflated in proportion to quantities produced. Figure 18 indicates the major oil and gas deposits in the state.

The mining of coal, a major resource in a 15,000 square-mile area of eastern Oklahoma, is gaining renewed interest. Coal beds in this region range in thickness from one to eight feet with approximately 7.2 billion tons of coal available.

Thick sequences of salt underlie most of western Oklahoma at depths of 30 to 30,000 feet, and reserves estimated at 20 trillion tons remain

FIGURE 20 AVERAGE ANNUAL RUNOFF (In Inches)
Period 1931-1960



Data—U.S. Geological Survey
Mapping—Oklahoma Water Resources Board

virtually untapped. Current salt production is from three solar evaporation plants located in Harmon and Woods Counties. Brines are obtained through relatively shallow wells drilled into salt beds. Dissolution of the salt by penetrating ground water yields natural brines that are pumped from the wells to solar evaporating pans for precipitation of crystalline salt. Underground storage facilities are easily and economically made by dissolving salt and forming cavities in salt beds.

Other resources produced in the state are dolomite, limestone, granite, sand and gravel, glass sand, gypsum, lead and zinc. Dolomite and limestone deposits are located primarily in northeastern Oklahoma and in the Arbuckle Mountains. Granite is quarried near Snyder and Granite in southwestern Oklahoma, and sand and gravel pits are located throughout the state. Glass sand, used in the manufacture of high purity glass, is produced in the south central region. Gypsum outcrops located in western Oklahoma produce 800,000 tons annually. Approximately 1.3 million tons of lead and 5.2 million tons of zinc have been mined from deposits in Ottawa County over the past 80 years. Figure 19 shows the types and locations of the mineral resources in Oklahoma.

WATER RESOURCES

Stream Water

RUNOFF

Runoff is a measure used to identify the amount of water from any form of precipitation that flows over the surface. The runoff, ranging from 0.2 inches in the Panhandle to 20 inches in the southeast corner, reflects the dramatic contrast in precipitation levels in Oklahoma. See Figure 20 . In the northwest region average runoff amounts to about 820,000 acre-feet per year, compared to six million acre-feet per year for the southeast region. Annual average runoff for the entire state is approximately 22 million acre-feet.

In an effort to accumulate relevant data on state stream water flows, the Oklahoma Water Resources Board cooperates with the U.S. Geological Survey in maintaining gaging stations on selected streams throughout the state. These gages periodically record discharge levels at reservoir sites and flow rates at other strategic stream locations. This information is utilized in determining reservoir yields and in the appropriation of stream water rights. (Appendix B, Figure 3 shows the location of these streamflow gaging stations.)

MAJOR RIVER BASINS

Oklahoma is drained by two major rivers; the Arkansas River in the north, and the Red River in the south. These two mighty rivers enter Oklahoma from neighboring states, pick up volume from several major tributaries, then flow out of the state toward their confluence with the Mississippi. The average amount of water leaving the state annually through these two basins is an estimated 34 million acre-feet; with the Arkansas River carrying 22 million acre-feet, the Little River (tributary of the Red) three million, and the Red River nine million. Despite these awesome quantities, their beneficial uses are limited by poor water quality.

The *Arkansas River* and its tributaries drain 44,491 square miles (28,762,240 acres), or about two-thirds of Oklahoma. Major tributaries of the Arkansas River are the Canadian, flowing almost the width of the state; the Illinois, Verdigris and Grand (Neosho) Rivers in the northeast, and the Poteau River in the southeast. Also among the Arkansas' major tributaries are the brackish Cimarron River and the Salt Fork. The Arkansas River enters Oklahoma from Kansas, near Newkirk in Kay County; flows southeasterly from Tulsa; continues that path to a point north of Muskogee, then flows out of the state near Fort Smith, Arkansas. It supports many major reservoirs, as well as the McClellan-Kerr Navigation System that connects the Tulsa area with the Gulf ports of the southeastern United States.

The *Red River* and its tributaries drain 24,978 square miles (15,985,920 acres), or about one-third of Oklahoma. The Red rises in the High Plains of eastern New Mexico, flows eastward across the Texas Panhandle, then marks the boundary between Texas and Oklahoma. It skirts the southern edge of the Kiamichi Mountains in southeastern Oklahoma, meanders across southwestern Arkansas and the coastal plain of Louisiana to its confluence with the Atchafalaya River, and finally joins the Mississippi River. Major tributaries of the Red in Oklahoma are the Elm, Salt and North Forks in the southwest; the Washita River which meets the Red at Lake Texoma; the Blue, Little and Kiamichi Rivers and Boggy Creek in the southeast. Lake Texoma is the only major reservoir project on the main stem of the Red River in the State of Oklahoma.

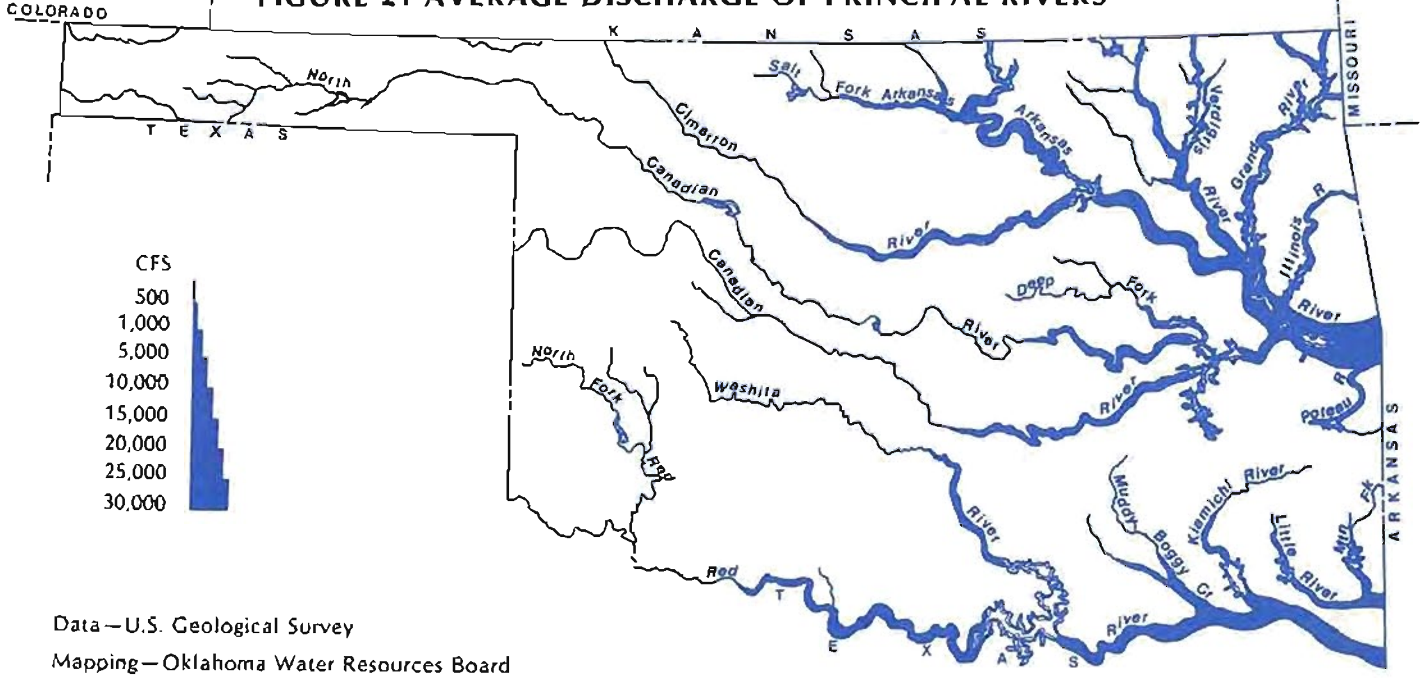
In order to effectively manage the state's large rivers and smaller streams, the Oklahoma Water Resources Board has further divided the Arkansas and Red River into 49 subbasins. Figure 1 shows the 23 subbasins of the Red and the 26 of the Arkansas. Such disaggregation facilitates the hydrologic studies necessary in the adjudication of stream water rights, implementation of the area of origin protection, reservoir operation surveys and other engineering and hydraulic analyses. (Appendix B, Figure 2 summarizes by planning region pertinent data for selected USGS stream gaging stations.)

STREAM WATER QUALITY

Water quality of Oklahoma's streams is adversely affected by natural and man-made pollution. In the west, natural salt springs and salt flats emit into local streams large quantities of chlorides that are subsequently carried downstream, polluting other major streams as they go. In populous central and eastern Oklahoma, municipal and industrial effluents degrade many streams, restricting their beneficial uses. However, many of the streams in eastern Oklahoma are of excellent quality, consistently providing pure, fresh water in large quantities.

A discussion of the quality of water rests primarily on the type and amount of materials dissolved in any given water resources. The characteristics of these dissolved materials depend on such factors as geology, flow characteristics of streams and man's activities. Water

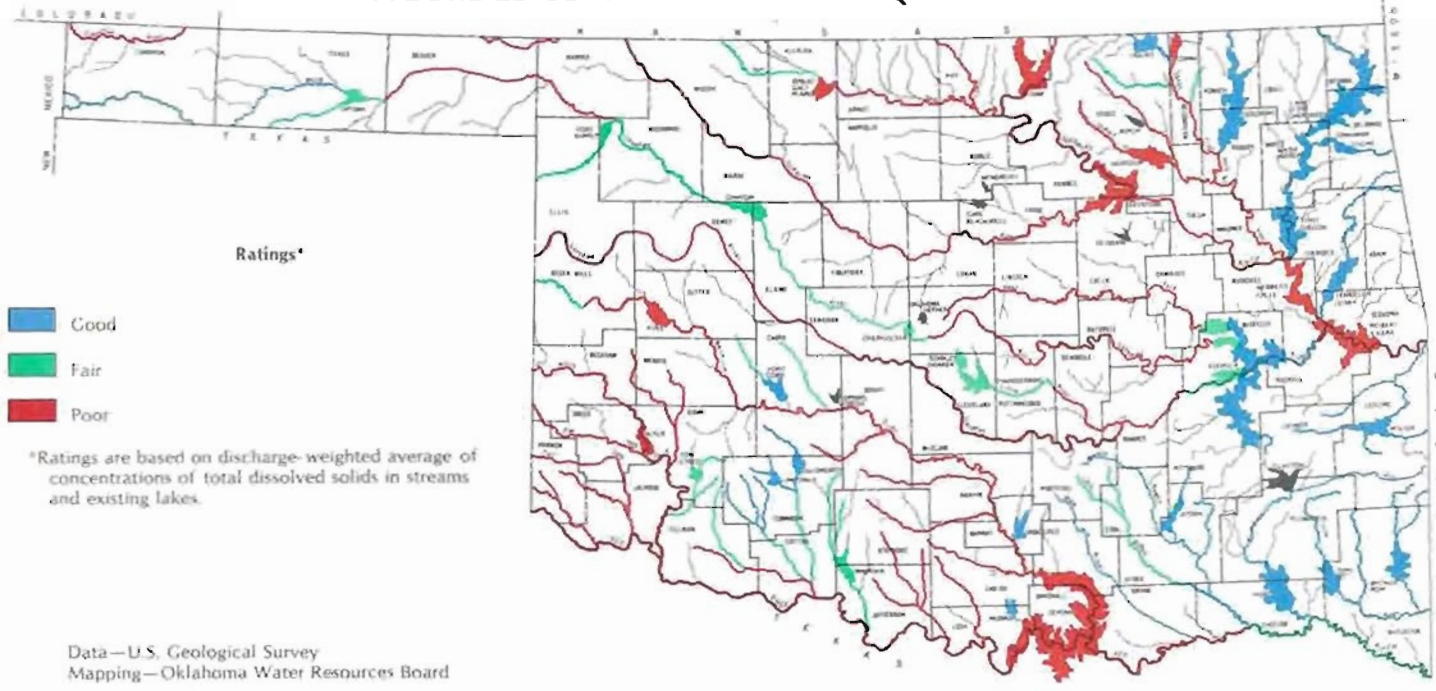
FIGURE 21 AVERAGE DISCHARGE OF PRINCIPAL RIVERS



Data—U.S. Geological Survey

Mapping—Oklahoma Water Resources Board

FIGURE 22 GENERALIZED WATER QUALITY



falling as rain contains minute amounts of dissolved materials, but as this water moves over and through rock and soil, more materials are brought into solution. Man-made pollution also places soluable material in water, further degrading its quality.

Water of the Arkansas River Basin in the western and central portions of the state is highly mineralized and nutrient-rich. The Salt Fork and Cimarron River Basins are highly mineralized by natural chloride emission zones in their upper basins. The amount of chloride concentration is so great in some reaches of the Cimarron that the salt level often exceeds that of sea water. The Cimarron also contains high levels of gypsum, which contribute to the river's poor water quality.

The North Canadian, Deep Fork and Canadian Rivers are also nutrient-rich and highly mineralized. Municipal and industrial discharges in central Oklahoma have degraded these rivers in recent years, however, the water quality improves in the lower reaches, as the assimilative capacity of the streams increases

Northeastern Oklahoma offers both good quality and poor quality streams. The Grand (Neosho) and Illinois Rivers are of excellent quality from their origin to their confluence with the Arkansas River. However, the Verdigris and Caney Rivers are rated poor due to high total dissolved solids from natural and man-made sources. Because of its degraded western tributaries, the main stem of the Arkansas is also of poor quality.

The general water quality of the Red River Basin is poor from the Texas Panhandle to Lake Texoma due to high mineral and nutrient levels. Natural salt plains in the lower Texas Panhandle, similar to those of northwestern Oklahoma, emit high levels of chlorides into the Red River making it unfit for beneficial use. The Salt Fork and North Fork drainage basins in Oklahoma also add chlorides to the Red, raising its total dissolved solids to undesirable levels. The highly nutrified East Cache Creek and moderately nutrified Mud Creek flow into the Red in Cotton and Jefferson Counties, respectively, further polluting the river. The Washita River, the major tributary of the Red, is a turbid, hard water stream, increasing in turbidity and hardness in its flow downstream. From its headwaters to Lake Texoma, the river is highly mineralized with sulfates and chlorides.

Once the Red River flows from Lake Texoma, the quality of its water improves significantly with the addition of the high quality waters of Muddy Boggy and Clear Boggy Creeks and the Blue and Kiamichi Rivers in southeastern Oklahoma. The Blue River is low in mineralization and nutrification, while Muddy Boggy and Clear Boggy Creeks are turbid, soft water streams. The Kiamichi River is a high quality stream with low to moderate turbidity, soft water and low mineralization.

Figure 22 illustrates the chemical water quality in major reservoirs (existing or under construction), as well as the general quality range of the state's major rivers and tributary streams, in terms of the discharge-weighted average of concentrations of total dissolved solids. A discharge-weighted average represents the average concentration of dissolved solids in all flows of a stream over an extended period. Such averages provide a valid measure of the quality of the water which will be impounded in proposed and potential reservoirs. Data upon which Figure 22 is based were collected by the U.S. Geological Survey in cooperation with the Oklahoma Water Resources Board and other state and federal agencies. Water quality analyses data for selected USGS monitoring stations and locations of the stations are shown in Appendix B, Figure 4 and 5 , respectively.

STREAM WATER DEVELOPMENT

Over the past three decades, Oklahoma has developed an impressive system of man-made lakes, developed through the efforts of the Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, Grand River Dam Authority and several state agencies and cities. In the 1920's there were only three major lakes in Oklahoma. During the 1930's and 1940's, 12 more were completed, however, during the past 30 years, 25 major lakes have been completed, and four more are currently under construction. Construction is scheduled to begin on two additional lakes in 1980, and five others are authorized by Congress. The McClellan-Kerr Arkansas River Navigation System, the largest civil works project ever undertaken by the Corps of Engineers, was extended to north of Tulsa in the 1970's, opening the way for extensive commercial and industrial development along the entire waterway.

More stream water development has occurred in the eastern portion of the state than in the west, where the drier climate has afforded limited opportunities In many areas of the state there are restrictions on further development due to the unavailability of water for appropriation and/or poor water quality.

Most major lakes in Oklahoma have been designated as multipurpose projects, allocating storage space for flood control and conservation purposes such as municipal and industrial water supply, irrigation

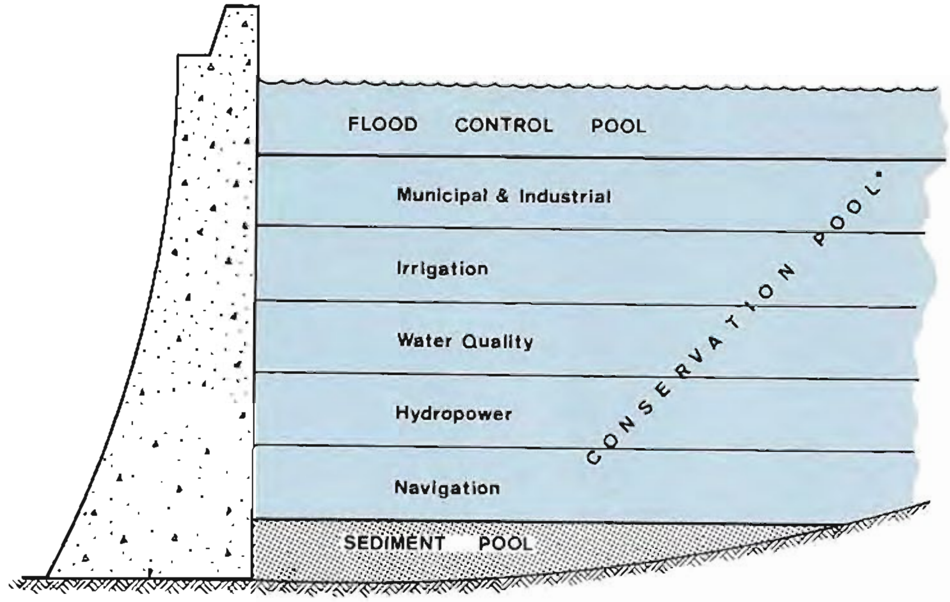


FIGURE 23 STORAGE SPACE IN A TYPICAL MULTIPURPOSE RESERVOIR

water supply, water quality control, recreation, fish and wildlife propagation, navigation and hydropower uses. Figure 24 presents pertinent data on the major developed and authorized water resources development projects in Oklahoma.

Figure 23 illustrates in cross section the storage space in a typical multipurpose reservoir. Most large reservoirs contain space for sedimentation storage, which continually fills throughout the life of the project as silt from the stream is deposited in the lake, thereby reducing the lake's yield. Above the sedimentation storage lies conservation storage, and above that, storage for flood control.

Flood Control

Severe thunderstorms moving across the state each year cause flooding problems throughout Oklahoma. Since cities and towns and productive agricultural bottomland must be assured protection against flooding, most federal reservoirs include flood control as a major purpose. Federal agencies design a reservoir's flood control pool to accommodate the most severe potential flood, based upon the drainage area and historical data. The flood control pool is usually designed to contain the 50-year or 100-year flood of record and, in some cases, the 500-year flood. Oklahoma has almost 14 million acre-feet of flood control storage in major existing lakes and those under construction.

Municipal and Industrial

Municipal and industrial water supply storage in a federal reservoir is purchased by the water user through a repayment contract with the construction agency, i.e., the Soil Conservation Service, Corps of Engineers or Bureau of Reclamation. Such a contract entitles the user to withdraw water directly from the lake or divert water downstream after requesting a release. Municipal and industrial storage amounts to approximately 85 percent of the total water supply storage in Oklahoma's developed reservoirs.

Irrigation

In eastern Oklahoma irrigation water supply comes primarily from natural precipitation, however in western Oklahoma, average annual precipitation does not supply adequate water, so irrigation farmers supplement rainfall with water from ground water sources, by direct diversion from streams or with water from irrigation storage in reservoirs. Since irrigation is generally confined to the

FIGURE 24 WATER RESOURCE DEVELOPMENT PROJECTS

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (AF)	WATER SUPPLY STORAGE (AF)	WATER SUPPLY YIELD (AF/YR)	CONSTRUCTION AGENCY□	DATE OF COMPLETION	
Altus Lake	North Fork of Red River	WS, FC, R, I	19,600	146,000	18,600	BR ~	Dec	1948
Arbuckle Lake	Rock Creek	WS, FC, R, FW	36,400	62,600	22,700	BR ~	Jan	1967
Arcadia Lake +	Deep Fork	WS, FC, R	70,700	27,380	12,100	COE	Oct	1984
Atoka Lake	North Boggy Creek	WS, R	0	123,500	65,000	City of Okla. City		1964
Birch Lake	Birch Creek	WS, FC, WQ, R, FW	39,000	15,200	6,700	COE	Mar	1977
Broken Bow Lake	Mountain Fork River	WS, FC, P, R, FW, WQ	450,000	152,500	196,000	COE	Apr	1970
Candy Lake +	Candy Creek	WS, FC, R, FW	31,260	43,100	8,620	COE	Jul	1982
Canton Lake	North Canadian River	WS, FC, I	267,800	107,000'	13,440	COE	Jul	1948
Lake Carl Blackwell	Stillwater Creek	WS, R	0	55,000	7,000	U.S. Dept. of Agric.		1948
Clayton Lake +	Jack Fork Creek	WS, FC, R, FW	128,200	297,200	156,800	COE	Oct	1985
Copan Lake +	Little Caney River	WS, FC, WQ, R, FW	184,300	33,600	21,300	COE	Oct	1981
Draper Lake	East Elm Creek	WS, R	0	100,000	86,000'	City of Okla. City		1962
Lake Ellsworth	East Cache Creek	WS, R	0	68,700	9,500	City of Lawton		1962
Eucha Lake	Spavinaw Creek	WS, R	0	79,600	84,000'	City of Tulsa		1952
Eufaula Lake	Canadian River	WS, FC, N, P	1,470,000	56,000	56,000	COE	Feb	1964
Fort Cobb Lake	Cobb Creek	WS, FC, R, I	63,330	78,350	13,300	BR	Nov	1959
Fort Gibson Lake	Grand (Neosho) River	FC, P	919,200	0	0	COE	Sept	1953
Fort Supply Lake	Wolf Creek	WS, FC, R	86,800	400	220	COE	May	1942
Foss Lake	Washita River	WS, FC, R, I	180,400	203,700	18,000	BR -	Feb	1961
Grand Lake O'the Cherokees	Grand (Neosho) River	FC, P	525,000	0	0	GRDA -		1940
Great Salt Plains Lake	Salt Fork of Arkansas River	FC, R	240,000	0	0	COE	May	1941
Lake Hefner	Bluff Creek	WS, R	0	75,000	17,000	City of Okla. City		1943
Heyburn Lake	Polecat Creek	WS, FC, conservation	48,400	2,000	1,900	COE	Sept	1950
Hudson Lake	Butler Creek	FC, P	244,200	0	0	GRDA -		1964
Hugo Lake	Kiamichi River	WS, FC, WQ, R, FW	809,100	121,500	165,800	COE	Jan	1974
Hulah Lake	Caney River	WS, FC, low flow regulation	257,900	27,000	19,000	COE	Sept	1951
Kaw Lake	Arkansas River	WS, FC, WQ, R, FW	866,000	203,000	230,700	COE	May	1976
Keystone Lake	Arkansas River	WS, FC, P, FW	1,218,500	20,000	22,400	COE	Sept	1964
Lake Lawtonka	Cache Creek	WS, R	0	64,000	8,500	City of Lawton		1905
McAlester Lakes	Coal Creek	WS, FC, R	25,000	24,300	10,500	City of McAlester		1923
McGee Creek Lake +	McGee Creek	WS, FC, R	85,000	109,800	71,800	BR -	Oct	1985
Lake McMurtry	North Stillwater Creek	WS, FC, R	5,000	13,500	3,000	City of Stillwater		1971
Lake Murray	Tributary of Hickory Creek	R	0	0	0	State of Oklahoma		1937
Oologah Lake	Verdigris River	WS, FC, N	965,600	342,600	172,500	COE		1974
Optima Lake	North Canadian River	WS, FC, R, FW	71,800	76,200	5,400	COE	Sept	1978
Lake Overholser	North Canadian River	WS, R	0	17,000	5,000	City of Okla. City		1919
Pine Creek Lake	Little River	WS, FC, WQ, FW	388,100	70,500	134,400	COE	Jun	1969
Lake Ponca	Big and Little Turkey Creeks	WS, R	0	15,300	9,000	City of Ponca City		1935
Robert S. Kerr Lake	Main Stem Arkansas River	N, P, R	0	0	0	COE	Oct	1970
Shawnee Lakes	South Deer Creek	WS, R	0	34,000	4,400	City of Shawnee		1935
Skiatook Lake +	Hominy Creek	WS, FC, WQ, R, FW	182,300	304,800	85,100	COE	Oct	1982
Sooner Lake	Greasy Creek	P, FC, R	47,500	149,000	3,600	Okla. Gas & Elect.	Jul	1976
Spavinaw Lake	Spavinaw Creek	WS, R	0	30,600	—'	City of Tulsa		1924
Tenkiller Lake	Illinois River	FC, P, WS, R	576,700	25,400	17,900	COE	Jul	1953
Lake Texoma	Red River	WS, FC, P	2,669,000	22,100	23,700	COE	Jan	1944
Lake Thunderbird	Little River	WS, FC, R	76,600	105,900	21,700	BR -	Mar	1965
Tom Steed Lake	Otter Creek	WS, FC, R	19,500	88,160	16,000	BR -		1977
Waurika Lake	Beaver Creek	WS, FC, WQ, R, FW, I	131,900	170,200	44,800	COE	Aug	1977
Webbers Falls Lock & Dam	Arkansas River	N, P, R, FW	0	0	0	COE	Dec	1970
Wister Lake	Poteau River	WS, FC, R, FW	400,000	9,600	6,700	COE	Oct	1949
SUBTOTAL			13,801,090	3,771,290	1,894,280			

AUTHORIZED

				CONSERVATION STORAGE				
Boswell Lake	Boggy Creek	WS, FC, R, FW	1,096,000	1,243,800	621,400	COE		
Lukfata Lake	Glover Creek	WS, FC, R, FW	208,600	37,500	59,400	COE		
Sand Lake	Sand Creek	WS, FC, WQ, R, FW	51,700	35,000	13,450	COE		
Shidler Lake	Salt Creek	WS, FC, R, FW	49,050	54,900	16,800	COE		
Tuskahoma Lake	Kiamichi River	WS, FC, R, FW	138,600	231,000	223,900	COE		
SUBTOTAL			1,543,950	1,602,200	934,950			
TOTAL			15,345,040		2,829,230			

* WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation

\+ Under Construction

□ BR-Bureau of Reclamation, COE-Corps of Engineers, GRDA-Grand River Dam Authority

— Lake Stanley Draper is a terminal storage reservoir for the existing pipeline from Atoka Lake and McGee Creek Lake (under construction). The 86,000 acre-feet per year yield shown is the capacity of the Atoka Pipeline (90 mgd) minus evaporation losses from Draper Lake. The 86,000 acre-feet per year yield is not included in the total

± Combined yield of both lakes

~ Includes irrigation storage

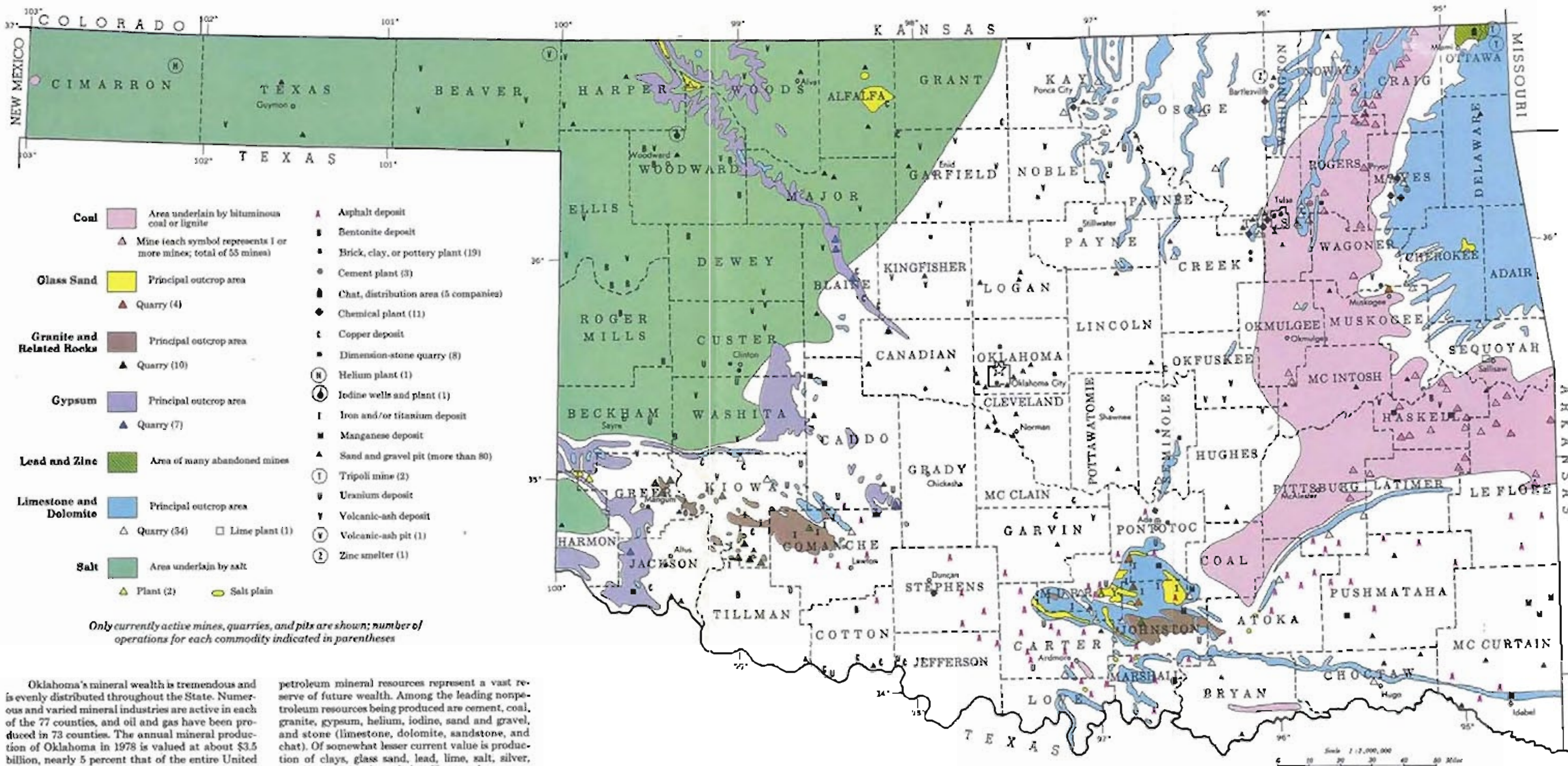
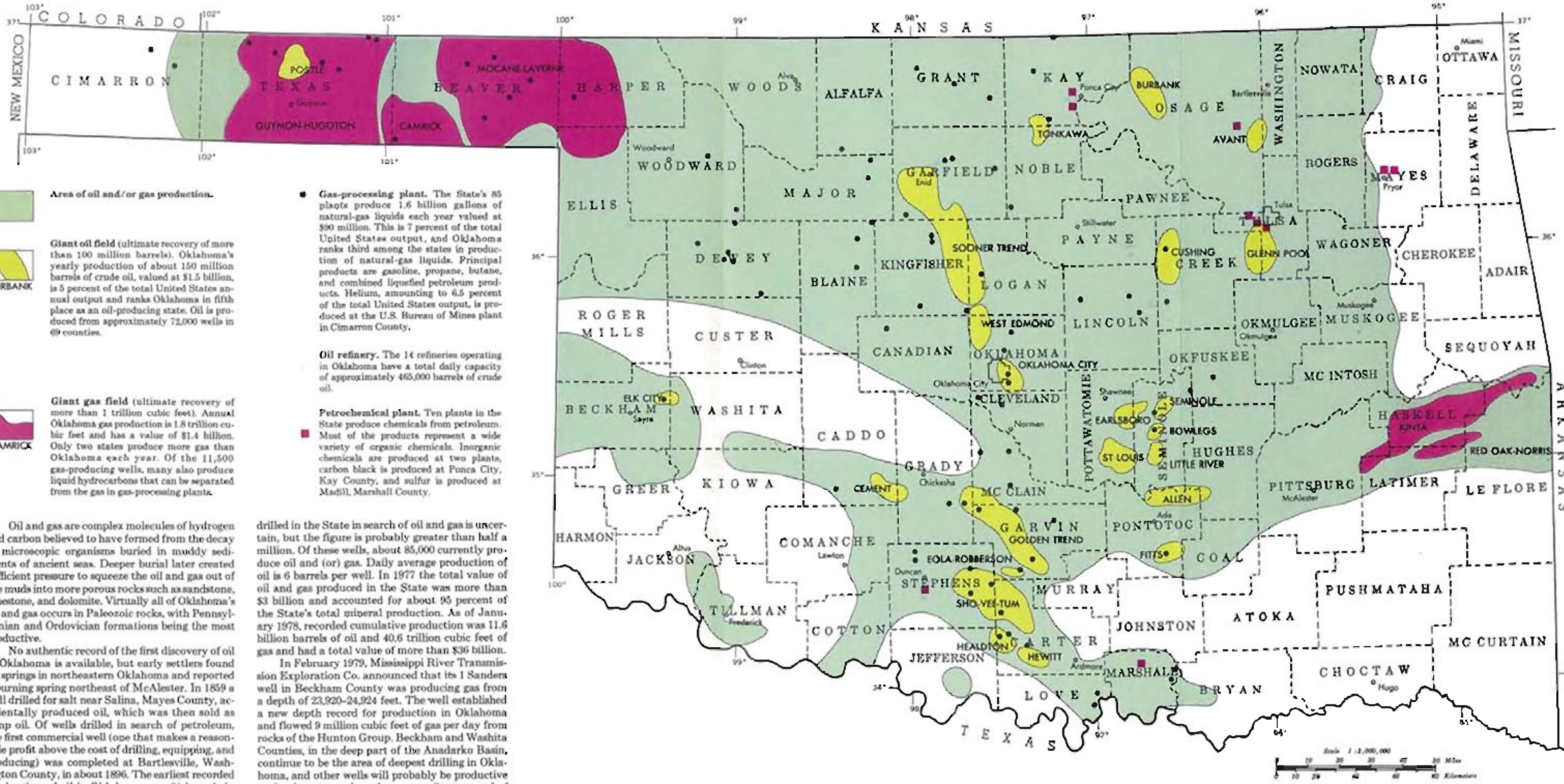


FIGURE 19 MINERAL RESOURCES

Oklahoma's mineral wealth is tremendous and is evenly distributed throughout the State. Numerous and varied mineral industries are active in each of the 77 counties, and oil and gas have been produced in 73 counties. The annual mineral production of Oklahoma in 1978 is valued at about $3.5 billion, nearly 5 percent that of the entire United States, and the State is the fourth leading mineral producer in the nation. Total production since statehood (1907) is valued in excess of $47 billion. Oklahoma is well known as an oil state, and petroleum (including crude oil, natural gas, and natural-gas liquids) accounts for about 94 percent of the State's yearly mineral output. However, nonpetroleum mineral resources represent a vast reserve of future wealth. Among the leading nonpetroleum resources being produced are cement, coal, granite, gypsum, helium, iodine, sand and gravel, and stone (limestone, dolomite, sandstone, and chat). Of somewhat lesser current value is production of clays, glass sand, lead, lime, salt, silver, tripoli, volcanic ash, and zinc. Untapped resources include iron, manganese, titanium, and uranium. Oklahoma ranks first among the states in production of iodine, second in helium and tripoli, third in liquefied petroleum gas and natural gas, and fifth in crude oil and gypsum.



Area of oil and/or gas production.

Giant oil field (ultimate recovery of more than 100 million barrels). Oklahoma's yearly production of about 150 million barrels of crude oil, valued at $1.5 billion, is 5 percent of the total United States annual output and ranks Oklahoma in fifth place as an oil-producing state. Oil is produced from approximately 72,000 wells in 69 counties.

BURBANK

Giant gas field (ultimate recovery of more than 1 trillion cubic feet). Annual Oklahoma gas production is 1.8 trillion cubic feet and has a value of $1.4 billion. Only two states produce more gas than Oklahoma each year. Of the 11,500 gas-producing wells, many also produce liquid hydrocarbons that can be separated from the gas in gas-processing plants.

CAMRICK

Gas-processing plant. The State's 85 plants produce 1.6 billion gallons of natural-gas liquids each year valued at $90 million. This is 7 percent of the total United States output, and Oklahoma ranks third among the states in production of natural-gas liquids. Principal products are gasoline, propane, butane, and combined liquefied petroleum products. Helium, amounting to 6.5 percent of the total United States output, is produced at the U.S. Bureau of Mines plant in Cimarron County.

Oil refinery. The 14 refineries operating in Oklahoma have a total daily capacity of approximately 465,000 barrels of crude oil.

Petrochemical plant. Ten plants in the State produce chemicals from petroleum. Most of the products represent a wide variety of organic chemicals. Inorganic chemicals are produced at two plants, carbon black is produced at Ponca City, Kay County, and sulfur is produced at Madill, Marshall County.

Oil and gas are complex molecules of hydrogen and carbon believed to have formed from the decay of microscopic organisms buried in muddy sediments of ancient seas. Deeper burial later created sufficient pressure to squeeze the oil and gas out of the muds into more porous rocks such as sandstone, limestone, and dolomite. Virtually all of Oklahoma's oil and gas occurs in Paleozoic rocks, with Pennsylvanian and Ordovician formations being the most productive.

No authentic record of the first discovery of oil in Oklahoma is available, but early settlers found oil springs in northeastern Oklahoma and reported a burning spring northeast of McAlester. In 1859 a well drilled for salt near Salina, Mayes County, accidentally produced oil, which was then sold as lamp oil. Of wells drilled in search of petroleum, the first commercial well (one that makes a reasonable profit above the cost of drilling, equipping, and producing) was completed at Bartlesville, Washington County, in about 1896. The earliest recorded production of oil in Oklahoma was 30 barrels in the year 1901.

Detailed data are available on oil and gas exploration in Oklahoma since 1933, but unfortunately records on the number of wells drilled during the boom years prior to that time are incomplete. Therefore, the total number of wells drilled in the State in search of oil and gas is uncertain, but the figure is probably greater than half a million. Of these wells, about 85,000 currently produce oil and (or) gas. Daily average production of oil is 6 barrels per well. In 1977 the total value of oil and gas produced in the State was more than $3 billion and accounted for about 95 percent of the State's total mineral production. As of January 1978, recorded cumulative production was 11.6 billion barrels of oil and 40.6 trillion cubic feet of gas and had a total value of more than $36 billion.

In February 1979, Mississippi River Transmission Exploration Co. announced that its 1 Sanders well in Beckham County was producing gas from a depth of 23,920-24,924 feet. The well established a new depth record for production in Oklahoma and flowed 9 million cubic feet of gas per day from rocks of the Hunton Group. Beckham and Washita Counties, in the deep part of the Anadarko Basin, continue to be the area of deepest drilling in Oklahoma, and other wells will probably be productive at depths greater than the current State record of 24,924 feet. Beckham County is also the location of the world's deepest borehole. In 1974 the Lone Star 1 Rogers was drilled to a total depth of 31,441 feet and thus claimed the depth record from a Washita County well, the Lone Star 1 Baden, which had been drilled to a total depth of 30,050 feet in 1972.

FIGURE 18 GENERALIZED OIL & GAS RESOURCES

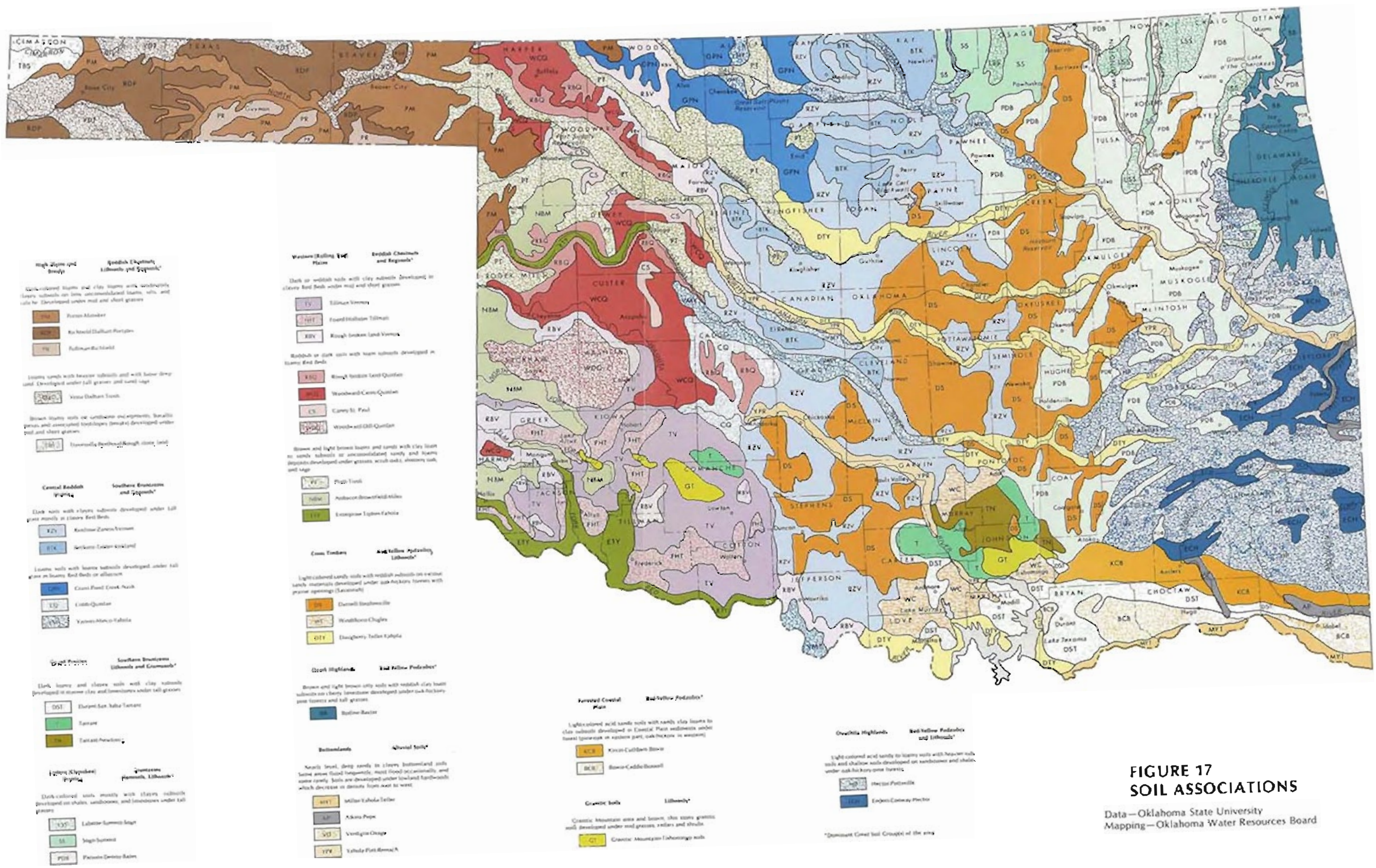


FIGURE 17
SOIL ASSOCIATIONS

Data—Oklahoma State University
Mapping—Oklahoma Water Resources Board

dry summer months, irrigation water supply is not required on as constant a basis as municipal and industrial waters. Fifteen percent of the state's total water supply storage in developed reservoirs is allocated for irrigation purposes, and is contracted for in the same manner as municipal and industrial storage. Traditionally, only the Bureau of Reclamation and the Soil Conservation Service have constructed reservoirs providing irrigation storage, however Canton and Waurika Lakes, constructed by the Corps of Engineers, contain some irrigation storage.

Water Quality Control

Water quality has become a concern of increasing importance to state and federal water authorities. In past years, Congress has recognized benefits derived from controlling water quality problems. As a result, if it is determined that downstream water quality would benefit from periodic reservoir releases, a reservoir may include water quality as an authorized purpose. Eight major Oklahoma reservoirs built or under construction are authorized for water quality purposes. Because pollutants have been reduced significantly by more stringent pollution control laws, not all the present water quality control storage is needed or utilized. The Oklahoma Water Resources Board has issued water rights for municipal and industrial use on a portion of the water quality control storage in these lakes, contingent upon Congress authorizing the conversion of the water quality control storage to water supply storage. Numerous reallocation studies by the Corps of Engineers are presently underway to determine if such reallocation is justified.

Recreation

Recreation as an authorized project purpose attracts visitors for boating, skiing and fishing. Since recreation is considered incidental to water supply, storage for recreational water is normally not contracted for. Fluctuations in lake levels resulting from regular reservoir operations can adversely affect recreational opportunities. However, since there is no contract to maintain levels for recreational purposes, no guarantee of recreational privileges can be provided. If it were determined worthwhile to maintain lake levels for these purposes, the beneficiaries would have to pay for that storage allocation.

Fish and Wildlife

Fish and wildlife are dependent on the quality of the environment, and many species are sensitive to the changes caused by development of water and related land resources. Although water is essential to the survival of fish and wildlife, the quantity and quality required by different species vary enormously. Reservoirs are authorized for fish and wildlife purposes in order to preserve and enhance an area's environmental resources, and are usually achieved through periodic releases to maintain minimum downstream flows. However, in some streams, particularly those of western Oklahoma, base flows are frequently zero, making minimum flows an unattainable goal. In any case, consideration of fish and wildlife resources is appropriate in the operation of all reservoirs.

Navigation

Completion of the McClellan-Kerr Arkansas River Navigation System by the Corps of Engineers in 1970 brought vigorous industrial growth along the channel, spurring economic activity in surrounding areas and increasing the commerce opportunities for all of Oklahoma.

The 448-mile navigation channel extends from near the mouth of the Arkansas River to the Port of Catoosa northeast of Tulsa. The system is composed of a series of 17 locks and dams, including five in Oklahoma. See Figure 25. The channel's 9-foot depth is maintained by periodic dredging. Major commodities transported on the system include bauxite, iron and steel, chemicals and chemical fertilizers, petroleum products, coal, sand and gravel, crushed stone, soybeans, wheat and other grains. Total tonnage has increased each year, achieving a record of approximately 10.2 million tons in 1978.

Only one reservoir in Oklahoma, Oologah Lake on the Verdigris River, contains navigation storage for release when necessary to maintain channel flows. However, hydroelectric power storage in several other reservoirs on the Arkansas River serves the additional purpose of providing navigation flow requirements.

Hydroelectric Power

There are 11 existing hydroelectric projects in Oklahoma with a total power storage of 5,103,600 acre-feet of water. Operation of a reservoir's power pool causes dramatic fluctuations in lake levels because of the great quantities of water that must pass through the generating turbines at one time. The power produced is marketed by the Grand River Dam Authority and/or the Southwest Power Administration. Figure 27 provides significant information on the existing hydroelectric projects in Oklahoma.

Soil Conservation Service

Upstream Watershed Program

As part of its upstream watershed program, the Soil Conservation Service has constructed thousands of flood control structures throughout the state, funded under four different Congressional authorizations.

The first watershed program was authorized in 1944 for the protection of 11 watersheds in the United States, including the Washita River in Oklahoma and Texas. A similar program initiated in 1953 provided for the installation of works on 60 pilot watersheds, among them Double Creek in Oklahoma. The Watershed Protection and Flood Control Act of 1954, along with its amendments, provides federal assistance in the installation of works of improvement on watersheds no larger than 250,000 acres, a maximum of 12,500 acre-feet of flood storage, and a total capacity for all purposes not to exceed 25,000 acre-feet in any one structure.

FIGURE 27 EXISTING HYDROELECTRIC PROJECTS

PROJECT	STREAM	POWER STORAGE AF	INSTALLED CAPACITY in Okla.	AVERAGE ANNUAL GENERATION in Okla	WATER USE (AF/YR)
Pensacola (Grand Lake)	Grand (Neosho)	544,200	86.4	311,000	3,507,000
Markham Ferry	Grand (Neosho)	200,300	108.0	190,000	4,544,000
Salina[1]	Chimney Rock Hollow	11,700	260.0	540,000	N/A
Keystone	Arkansas	310,500	70.0	228,000	3,134,000
Ft. Gibson	Grand (Neosho)	53,700	45.0	190,500	3,738,000
Webbers Falls	Arkansas	30,000	60.0	213,300	1,332,000
Robert S. Kerr	Arkansas	79,500	110.0	459,000	13,009,000
Tenkiller Ferry	Illinois	345,600	34.0	95,100	880,000
Eufaula	Canadian	1,481,000	90.0	260,300	3,735,000
Broken Bow	Mountain Fork	317,100	100.0	44,500	841,000
Denison	Red	1,730,000	70.0[2]	244,000	2,953,000
TOTAL		5,103,600	1,033.4	2,775,700	37,673,000

[1]Pump-back project designed to receive water during off-peak period then generate during peak periods.

[2]35,000 KW used in Oklahoma--35,000 KW used in Texas.

N/A — Not available

The fourth watershed progam, authorized by the Food and Agriculture Act of 1962, empowers the Secretary of Agriculture to provide technical assistance to sponsors of Resource Conservation and Development Projects. Financial assistance is provided under the Soil Conservation Act. Recent legislation has awarded the Secretary authority to include recreation and wildlife improvements in Resource Conservation and Development Projects providing for the conservation, development and use of water and related land resources through a small watershed approach.

As shown in Figure 26, 125 watersheds covering 11,556,300 acres are presently under development in the state, with 55 percent of this area protected by existing structures. Of the 2,558 structures planned, 1,908 are complete or under construction. Combined storage capacity in lakes existing or planned is approximately three million acre-feet. As of November 1979, the Soil Conservation Service has received applications for additional watersheds bringing the total to approximately 17 million acres.

In recent years increased emphasis has been placed on the development of multipurpose lakes constructed for floodwater detention. In addition to widespread recreational use of sediment pools of watershed structures, many local sponsors have added storage for municipal, irrigation, recreation and fish and wildlife purposes.

Multipurpose lakes foster economic growth in cities, towns and rural areas by providing dependable water supplies and recreational areas attractive to tourists and residents. Landowners in the watersheds, now secure against flood threats, have developed and intensified their farming and ranching operations, and also are utilizing these sites as sources of irrigation water.

Multipurpose lakes with municipal water supply storage capacities of 160,000 acre-feet are presently being utilized by cities and towns in Oklahoma. Structures with a water supply storage capacity of 50,000 acre-feet remain in planning stages. Multipurpose sites which have been identified for potential use as municipal water supply sources are shown in Figure 26.

Ground Water

Ground water, one of Oklahoma's most valuable resources, is available in almost every part of the state. Ground water is water that has percolated downward from the surface, filling voids or open spaces in rocks. Below a certain level, the voids are completely saturated with water. This is called the zone of saturation.

A rock formation or group of formations that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs is termed a ground water basin. The amount of water available to wells depends on the saturated thickness, areal extent and specific yield. The amount of water that can be pumped perennially without depletion of the ground water in storage depends on the amount of recharge from precipitation.

Ground water in Oklahoma is found in a variety of rock formations. Sand, gravel, limestone, dolomite, sandstone and gypsum are the major water-bearing formations. These range in age from Cambrian and Ordovician, represented by the Arbuckle Group, to Quaternary stream-laid deposits.

Twelve major ground water basins occur in Oklahoma with an estimated 320 million acre-feet of fresh water in storage, half of which is estimated to be recoverable. Less significant amounts are available in at least 150 minor basins. See Figure 28. Ground water supplies 61 percent of the total water reported used in Oklahoma, providing for over 80 percent of the state's irrigation and meeting the municipal needs of approximately 300 towns and cities.

Due to the lack of available stream water, ground water development is greatest in the western part of the state, where it is extensively used for irrigation, municipal and industrial purposes. Development is not as widespread in central and eastern Oklahoma, although great potential exists for further use if supplies remain unpolluted.

FIGURE 29 TOTAL GROUND WATER ESTIMATED RECOVERABLE FROM STORAGE

GROUND WATER BASIN	WATER IN STORAGE (1000 AF)	ESTIMATED[1] RECOVERABLE (PERCENT)	ESTIMATED[2] TOTAL AVAILABLE WATER (1000 AF)
Alluvium and terrace deposits	18,400	60	11,000
Ogallala Formation	76,000	60	46,000
Antlers Sand	70,000	40	28,000
Elk City Sandstone	1,400	40	1,000
Rush Springs Sandstone	31,200	50	16,000
Dog Creek Shale and Blaine Gypsum	600	50	300
Garber-Wellington Formation	52,000	50	26,000
Oscar Formation	8,900	40	4,000
Vamoosa Formation	36,000	40	14,000
Simpson Group	3,300	40	1,000
Arbuckle Group	15,000	50	8,000
Roubidoux	7,200	40	3,000
STATEWIDE TOTAL	320,000		159,000

[1]Based on quality, economic, legal and technological constraints.

[2]Will not equate because of rounding off.

MAJOR GROUND WATER BASINS

Alluvium and terrace deposits (Quaternary) consist of unconsolidated clay, silt, sand and gravel which interfinger and were deposited by streams in an irregular pattern. The alluvium underlies the bottomlands along the stream, while the terrace deposits are topographically higher and usually adjacent to the alluvium.

Thickness of the deposits ranges from 40 feet in southwestern Oklahoma to a maximum of 170 feet along the Cimarron River. In some deposits, the maximum saturated thickness is greater than 100 feet, but the average is 25 to 30 feet. Well yields commonly average 100 to 300 gallons per minute (gpm), but can be as high as 1,000 gallons per minute. Water quality is generally affected by nearby streams flowing along the deposits. Some quality problems are hardness and high sulfate and chloride concentrations. Where water quality is good, the water is used for domestic, irrigation, industrial and municipal supplies.

Ogallala Formation (Tertiary) consists of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The Ogallala covers an area of about 10,000 square miles, including all of Beaver, Texas and Cimarron Counties and parts of Harper, Woods, Ellis, Woodward, Roger Mills, Beckham and Dewey Counties. Total thickness ranges from zero to more than 700 feet, due to the irregular surface on which the Ogallala was deposited. Average thickness in the Panhandle is 300 feet.

The Ogallala is the major source of water in the Oklahoma Panhandle with over 2,000 irrigation wells drilled in the area. Most of the wells yield from 500 to 1,000 gallons per minute, averaging approximately 700 gallons per minute. The water is generally of a calcium magnesium bicarbonate type, containing between 200 and 500 mg/L of dissolved solids and, although hard, it is suitable for most uses.

In the southwest, the Ogallala is partly eroded and it also thins toward the east. In these areas yields can be as high as 800 gallons per minute, but due to thinning and erosion of the ground water basin, they are usually about 200 gallons per minute. Water quality is good with low dissolved solids content and, except for hardness, the water is suitable for most uses.

Ground water in the Ogallala is being used at a rate greatly exceeding that of recharge. As the water table is lowered by pumping and the saturated thickness is reduced, the yields of the wells decline. Depletion of the aquifer is expected to exert serious economic pressures on the area in the future.

Antlers Sand (Cretaceous) is part of the larger coastal plain deposits that crop out in a 10-mile wide belt in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties. The unit is a fine-grained sand interbedded with clay, unconsolidated and friable.

The Antlers Sand ranges in thickness from 180 feet in the west to more than 880 feet in the southeast. Water occurs under water table conditions, with well yields ranging from five to 50 gallons per minute for water table wells to 50 to 650 gallons per minute for artesian wells. An average yield for wells completed in the ground water basin is 100 to 150 gallons per minute.

The quality of the water is good in the outcrop areas, suitable for industrial, municipal and irrigation use. Downdip from the outcrop the quality of the water deteriorates. Dissolved solids range from 130 to 1,240 mg/L, hardness from 8 to 850 mg/L, sodium from 1 to 350 mg/L and bicarbonate from 10 to 580 mg/L

Due to the availability of surface water in the area, water from the Antlers Sand is not being utilized extensively at the present time.

Rush Springs Sandstone (Permian) is an extensive ground water basin outcropping over approximately 1,900 square miles in Caddo, Custer, Washita and small parts of Comanche, Dewey and Grady Counties. It is a fine-grained, crossbedded sandstone, containing irregular silty lenses. Thickness ranges from less than 200 feet in the south to about 330 feet in the northern part of the region. Depth below land surface to water ranges from zero to 150 feet. Wells yield as much as 1,000 gallons per minute and average about 400 gallons per minute. Most of the water is suitable for domestic, municipal, irrigation and industrial use.

Dissolved solids concentration in 39 samples ranged from 179 to 2270 mg/L, with the median concentration at 296 mg/L. Seventy-five percent of the wells sampled showed less than 450 mg/L dissolved solids, which is within the recommended (500 mg/L) level for drinking water. Median hardness is 179 mg/L.

Elk City Sandstone (Permian) occurs in western Washita and eastern Beckham Counties. It is similar to the Rush Springs ground water basin in being a fine-grained sandstone with little or no shale; however, it is of smaller areal extent and considerably thinner. Well yields range from 60 to 200 gallons per minute with water suitable in quality for most purposes.

Dog Creek Shale and Blaine Gypsum (Permian) occur in Harmon and parts of Jackson, Greer and Beckham Counties. The ground water basin consists of interbedded shale, gypsum, anhydrite, dolomite and limestone, which are characterized in places by solution channels and zones of secondary porosity. The yields from wells tapping the Dog Creek Shale and Blaine Gypsum range from less than 10 to as much as 2,000 gallons per minute. For a well to yield enough water for irrigation, it must tap a water-filled solution cavity.

Water levels in the ground water basin respond rapidly to infiltration of precipitation and also to the effects of pumping. Due to the erratic nature of solution channels and cavities, it is difficult to predict yields or estimate amounts in storage. Water quality is poor because of hardess and very high calcium sulfateconcentrations.Locally, in southeastern and northwestern Harmon County, the water has a high sodium chloride content. The water, although suitable for irrigation, is not drinkable.

Garber-Wellington Formation (Permian) consists of two formations: the Garber Sandstone and the Wellington Formation. The two units were deposited under similar conditions, both containing lenticular beds of sandstone alternating with shale, and are considered a single water-bearing unit.

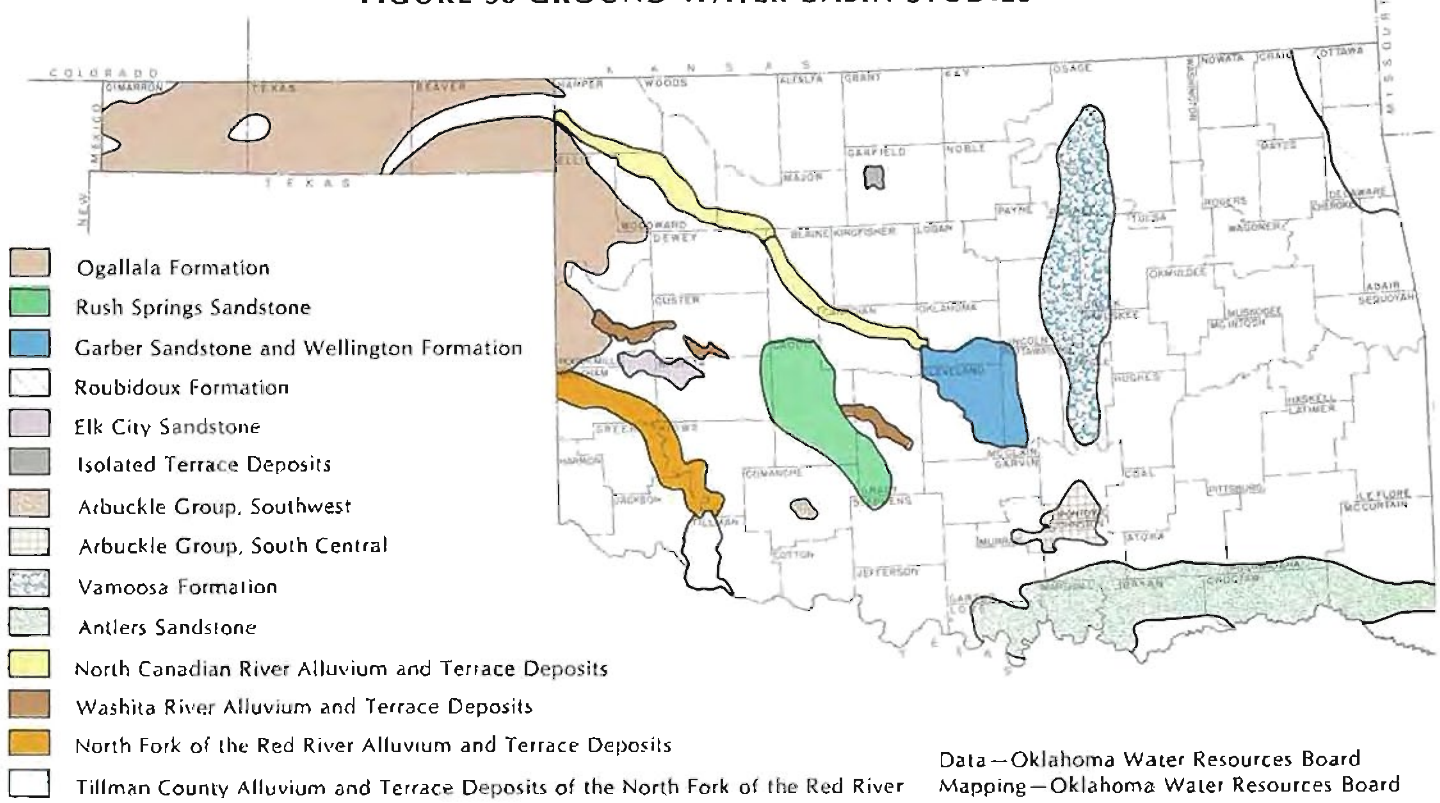
The total thickness of the combined formations is 800 to 1,000 feet. Depth to water varies from 100 feet or less in areas of outcrop to 350 feet in structural depressions such as that at Midwest City. Well yields range from 150 to 450 gallons per minute and average 250 gallons per minute. In Logan County, the formation is shaly with wells exhibiting yields of 10 gallons per minute or less near Guthrie. Natural recharge to the basin over the entire outcrop area is estimated at 130,000 acre-feet annually. Presently, the rate of natural recharge exceeds total discharge from the basin, as evidenced by static annual water levels. Pumpage cannot be estimated at this time, due to insufficient data, but will be determined following prior rights hearings.

The Garber-Wellington yields large amounts of good quality water for municipal, irrigation and industrial uses and exhibits potential for additional development to help meet central Oklahoma's future water needs.

Oscar Formation (Pennsylvanian) consists of interbedded shale, sandstone and limestone conglomerate with lithology varying from place to place. The formation is 300 to 400 feet thick and occurs in western Stephens, southwestern Garvin, southwestern Carter and eastern Jefferson Counties. Depth to water is generally 100 feet below the surface, and well yields range from 60 gallons per minute to as much as 400 gallons per minute, with 150 to 180 gallons per minute the common reported yield. Water quality is considered suitable for most purposes. The ground water basin is of major importance locally, but its potential over a broad area is unknown, due to lack of information and sparse well development.

Vamoosa Formation (Upper Pennsylvanian) is composed of 125 to 1,000 feet of interbedded sandstone, shale and conglomerate with proportions of shale increasing northward. The Vamoosa outcrops in Seminole, Okfuskee, Pottawatomie, Osage, Creek, Pawnee, Payne and Lincoln Counties and supplies water for municipal uses and secondary oil recovery operations. The most productive wells are in the Seminole area, where wells produce up to 500 gallons per minute. Yields decline northward, decreasing from 250 gallons per minute to 10 to 20 gallons per minute. Although water quality is generally good, brine infiltration and hardness present problems. Studies

FIGURE 30 GROUND WATER BASIN STUDIES



show the Vamoosa exhibits the potential for supplying large quantities of water to help meet the area's future water requirements if properly developed and managed.

Simpson Group (Ordovician) consists of fine-grained, loosely cemented and friable sandstones. The ground water basin crops out in an area of about 40 square miles in southwestern Murray and northeastern Carter Counties with wells commonly yielding 100 to 200 gallons per minute Water from the sandstones is of poor quality at Sulphur, but elsewhere in the region, it is usually drinkable.

Arbuckle Group (Cambrian-Ordovician), underlying parts of Murray, Pontotoc, Johnston and Comanche Counties, is limestone and dolomite, 5,000 to 6,000 feet thick. Relatively high permeability results from fractures, joints and solution channels in the limestone. This ground water basin produces large quantities of water, with wells in the area commonly yielding 200 to 500 gallons per minute Although the water may be hard, total dissolved solids are generally low and the quality is good, except for some areas in Comanche County, where high fluoride levels have been recorded. Well development in this aquifer is sparse at the present time

Roubidoux (Upper Cambrian-Lower Ordovician) consists mainly of sandy and cherty dolomite. The Roubidoux basin in this discussion includes the Roubidoux, Gasconade and Eminence-Potosi Formations, of which the Roubidoux Formation is the principal water-bearing unit. The Roubidoux does not outcrop on the surface, but is deeply buried beneath Ottawa and Delaware Counties and small parts of Craig and Adair Counties at depths of 450 to 1,700 feet. The artesian or confined water is under sufficient pressure to cause it to rise above the surface. With pumpage over a long period, the artesian head has declined, and presently the water is some wells is being lifted more than 500 feet to the surface. Yields are as much as 1,000 gallons per minute, but average 200 gallons per minute. Although the water is hard, it has a low total mineral content. In Ottawa County the water quality is suitable for most purposes and is characterized as a calcium bicarbonate type, but it changes to a sodium chloride type farther west, and thus becomes unusable.

GROUND WATER BASIN STUDIES

In order to fulfill the requirements of the Oklahoma Ground Water Law (1972), the Board must determine the maximum annual yield of ground water in each ground water basin or subbasin through the establishment of prior rights and completion of hydrologic surveys of the major basins and subbasins. (See Chapter II, "Oklahoma Water Law and its Adminstration.")

The determination of maximum annual yield is based on the total land overlying the basin or subbasin, amount of fresh ground water available for use, rates of recharge and discharge, and the possibility of natural pollution. The maximum annual yield is based upon a minimum basin life of 20 years from July 1, 1973, the effective date of the Ground Water Act.

Equal proportionate shares are allotted to overlying land owners according to the amount of ground water determined available by estimate of the maximum annual yield, assuming a basin life of 20 years. Any individual permitted to use ground water prior to July 1, 1973 is given the opportunity to establish a prior right

The Oklahoma Water Resources Board, in cooperation with the U.S. Geological Survey, Oklahoma Geological Survey, Oklahoma State University and the U.S. Department of Agriculture (Agricultural Research Service), has completed or is currently participating in studies of the ground water basins shown in Figure 30

Ogallala Formation, a cooperative study by the Oklahoma Water Resources Board and U.S. Geological Survey, produced a hydrologic atlas and data on geohydrology and subsurface geology, as well as determination of maximum annual yield, equal proportionate share and prior rights for the Panhandle counties underlain by the aquifer. Board approval of maximum annual yield and equal proportionate shares in this area is scheduled for 1980.

The Board also cooperates with the U.S. Geological Survey in the Regional Aquifer Study Analysis (RASA) to gather data for a 5-year computer model study on the entire Ogallala area in northwestern Oklahoma which has an expected completion date in 1984.

North Fork of the Red River alluvium and terrace deposits, a joint project of the Oklahoma Water Resources Board, Oklahoma State University and the Agricultural Research Service, accomplished hydrologic and computer model studies and determinations of maximum annual yield, equal proportionate share and prior rights for that portion of the aquifer in Tillman County which were approved by the Board in 1978. A computer model study to determine maximum annual yield and equal proportionate share has been completed and prior rights determined for alluvium and terrace deposits in the remaining area in Kiowa, Jackson, Greer and Beckham Counties. Approval of maximum annual yield and equal proportionate share in these areas is planned for 1980.

Rush Springs Sandstone, a project of the Oklahoma Water Resources Board, produced a hydrologic atlas. Determinations of prior rights, maximum annual yield and equal proportionate share are scheduled for 1980.

Garber Sandstone and Wellington Formation. The Oklahoma Water Resources Board completed a hydrologic atlas on the southern half in 1979 to complement studies on the northern portion of the aquifer completed by the U. S. Geological Survey and the Bureau of Reclamation in 1977. Prior rights determinations are planned for 1980.

Washita River alluvium and terrace deposits (from the Texas line in Roger Mills County to Alex, Oklahoma in Grady County). A computer model study by Oklahoma State University in cooperation with the Oklahoma Water Resources Board begun in 1979, with an expected completion date in 1981, will determine maximum annual yield and equal proportionate share. Determination of prior rights is planned for 1980, with approval of maximum annual yield and equal proportionate share scheduled for 1981.

North Canadian River alluvium and terrace deposits (Harper-Beaver County line to Canton Dam) Studies by the U.S. Geological Survey in cooperation with the Oklahoma Water Resources Board determined maximum annual yield, equal proportionate share and prior rights. Approval of maximum annual yield and equal proportionate share is planned for 1980

(Canton Dam to Oklahoma City Area). Studies by the U.S. Geological Survey and Oklahoma Water Resources Board begun in January 1980, will determine maximum annual yield, equal proportionate share and prior rights. Studies of this segment are scheduled for completion in 1982.

Elk City Sandstone. A computer model study begun in 1979 under the auspices of Oklahoma Water Resources Board and Oklahoma State University and scheduled for completion in 1980, will determine maximum annual yield and equal proportionate share. Prior rights determinations are planned for 1980, and approval of maximum annual yield and equal proportionate share is expected in 1981.

Isolated terrace deposits (Garfield County). A computer model study begun in 1979 by the Oklahoma Water Resources Board and Oklahoma State University to determine maximum annual yield and equal proportionate share is scheduled for completion in 1980, along with determination of prior rights. Approval of maximum annual yield and equal proportionate share is planned for 1981.

Arbuckle Group (southwest) was the subject of a joint study by U.S. Geological Survey and Oklahoma Geological Survey, who completed geologic, ground water availability and water quality data for the Wichita Mountain region in southwestern Oklahoma in 1978.

Arbuckle Group (south central). An inventory of wells and springs in this aquifer was completed by the U.S Geological Survey and Oklahoma Geological Survey, with water quality samples and geophysical logs collected on selected wells. Data collection, utilizing a network of observation wells, rain gauges and stream gaging stations, is scheduled for completion in 1980.

Vamoosa Formation is under study by the U.S Geological Survey and Oklahoma Geological Survey, who have produced geologic and hydrologic data analyses and published hydrologic data in 1977. The final report on the aquifer prepared by study participants is scheduled for review and publication in 1980.

Antlers Sandstone. A cooperative study by the U.S. Geological Survey and Oklahoma Geological Survey has produced data on geology, water quality, well locations and water table levels which have been plotted on maps. Hydrologic data was published in

1978, and the report is to be completed in 1980.

Roubidoux Formation is currently under study by the U.S. Geological Survey and Oklahoma Geological Survey. This investigation, scheduled for completion in late 1982, will produce data on water quality, thickness and distribution of water zones and hydraulic characteristics.

PRESENT WATER USE AND FUTURE REQUIREMENTS

Sharp escalations in population, industrial development, and irrigated agriculture, along with increased affluency and higher standards of living have placed heavy demands on the state's available water resources. Projections by the Oklahoma Employment Security Commission (OESC) forecast a population of 4.4 million by the year 2040 and over six million by the year 2090.

Since Oklahoma's water resources are not inexhaustible, planning for the optimal use of all potential supplies is imperative in order to assure all parts of the state adequate water.

Analysis of Oklahoma's historical population data indicates a trend toward greater concentrations in the urban areas. Industries, attracted by larger populations and available labor forces, typically locate in those areas, thereby placing even heavier demands on water supplies. Increased industrial activity in turn attracts more people, further increasing municipal water requirements, which then leads to greater demand for electrical power cooling water to supply such induced requirements.

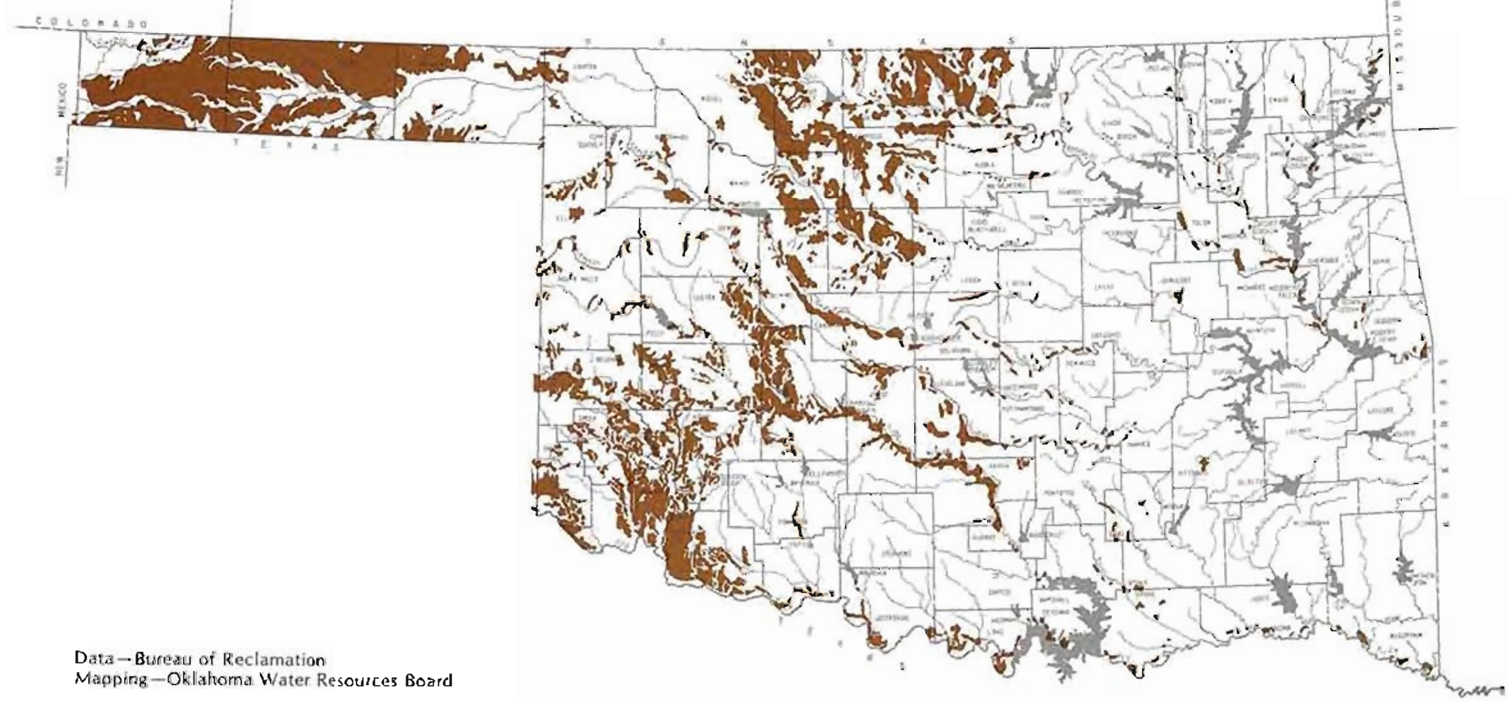
Current municipal water use in the state is estimated at 402,200 acre-feet per year; industrial use at 388,300 acre-feet; and use of cooling water for power generation at 110,900 acre-feet, totaling over 900,000 acre-feet annually. See Figure 31.

FIGURE 31
STATEWIDE PRESENT AND PROJECTED WATER REQUIREMENTS
(In 1,000 Af/Yr)

Planning Region	Use	Present	1990	2000	2010	2020	2030	2040
SOUTHEAST	Municipal	16.5	21.0	24.4	29.1	32.3	37.4	56.1
	Industrial	71.3	88.7	103.6	119.8	137.4	154.9	172.2
	Power	–	10.7	16.2	21.6	27.1	32.6	38.0
	Irrigation	13.9	46.9	94.3	141.1	188.2	235.5	282.4
	Total	101.7	167.3	238.5	311.6	385.0	460.4	548.7
CENTRAL	Municipal	113.7	167.2	191.8	228.0	264.1	324.5	351.6
	Industrial	55.6	88.8	119.2	149.5	179.9	226.3	272.6
	Power	18.5	39.5	59.6	79.6	99.7	110.1	120.4
	Irrigation	39.8	43.3	49.6	56.0	62.4	68.7	75.1
	Total	227.6	338.8	420.2	513.1	606.1	729.6	819.7
SOUTH CENTRAL	Municipal	20.4	24.7	27.3	30.8	34.3	36.0	37.8
	Industrial	34.0	34.5	35.4	36.5	37.6	38.1	38.7
	Power	1.0	1.8	2.9	3.6	4.2	4.5	4.9
	Irrigation	42.6	69.5	87.8	107.7	127.5	137.4	147.4
	Total	98.0	130.5	153.4	178.6	203.6	216.0	228.8
SOUTHWEST	Municipal	36.0	45.2	52.0	56.7	61.5	63.9	66.2
	Industrial	50.6	55.7	61.7	63.9	66.2	67.3	68.4
	Power	5.6	14.8	23.0	28.4	33.7	36.4	39.1
	Irrigation	504.4	576.4	631.3	827.4	1,023.0	1,121.0	1,219.1
	Total	596.6	692.1	768.0	976.4	1,184.4	1,288.6	1,392.8
EAST CENTRAL	Municipal	33.8	42.0	47.9	54.7	58.7	66.1	70.8
	Industrial	9.3	10.9	11.5	12.3	12.9	13.3	16.9
	Power	20.8	66.7	103.7	140.7	177.7	204.2	230.8
	Irrigation	9.5	29.3	32.7	36.0	39.4	42.9	46.6
	Total	73.4	148.9	195.8	243.7	288.7	326.5	365.1
NORTHEAST	Municipal	119.4	179.2	219.4	248.5	278.6	309.0	349.0
	Industrial	104.9	140.1	158.6	172.8	177.9	183.1	187.5
	Power	57.0	146.1	197.0	241.4	285.6	311.7	338.9
	Irrigation	26.0	51.0	60.4	70.3	80.0	87.9	95.6
	Total	307.3	516.4	635.4	733.0	822.1	891.7	971.0
NORTH CENTRAL	Municipal	45.6	58.1	67.4	77.3	85.5	93.9	101.6
	Industrial	47.6	48.9	49.4	51.5	53.0	54.1	59.3
	Power	4.6	42.9	66.7	90.6	114.4	138.3	162.1
	Irrigation	28.6	82.8	133.5	179.4	238.2	287.3	336.9
	Total	126.4	232.7	317.0	398.8	491.1	568.6	659.9
NORTHWEST	Municipal	16.8	19.1	20.6	22.9	24.4	26.0	27.6
	Industrial	15.0	15.2	15.3	15.9	16.3	16.3	17.8
	Power	3.4	5.6	8.7	11.9	15.0	18.2	21.3
	Irrigation	850.0	1,077.6	1,205.4	1,377.8	1,557.0	1,724.4	1,886.8
	Total	885.2	1,117.5	1,250.0	1,428.5	1,612.7	1,784.9	1,953.5
STATEWIDE TOTAL	Municipal	402.2	556.5	650.8	748.0	839.4	956.8	1,060.7
	Industrial	388.3	482.8	554.7	622.2	681.2	753.4	833.4
	Power	110.9	328.1	477.8	617.8	757.4	856.0	955.5
	Irrigation	1,514.8	1,976.8	2,295.0	2,795.7	3,315.7	3,700.1	4,089.9
	Total	2,416.2	3,344.2	3,978.3	4,783.7	5,593.7	6,266.3	6,939.5

The early economy of Oklahoma revolved around agriculture as settlers gravitated to the state's favorable climate, soil and abundant lands. Today agriculture remains the leading economic activity, and agribusiness has evolved to complement traditional farming and ranching activities. Approximately 895,000 acres were devoted to irrigated agriculture in 1977, as shown in Figure 13, with approximately 1.6

FIGURE 32 LANDS SUITABLE FOR PROJECT-TYPE IRRIGATION



Data—Bureau of Reclamation
Mapping—Oklahoma Water Resources Board

million acre-feet of water per year being used for irrigation. Western Oklahoma accounts for over 80 percent of this total, primarily utilizing ground water pumped from the Ogallala Formation and alluvium and terrace deposits. An exception is the Altus-Lugert Irrigation District in Jackson County which utilizes surface water from Altus Reservoir, a Bureau of Reclamation project, for the irrigation of appoximately 47,000 acres. The potential for increased irrigation development is excellent in western Oklahoma, primarily due to soil suitability.

Figure 32 indicates the general extent of lands in the state suitable for potential long-term, project-type irrigation development. Approximately 4.7 million acres have been given this classification, based on land classification studies conducted by the Bureau of Reclamation. Irrigation suitability land classifications are conducted for the prupose of establishing the extent and degree of suitability of lands for sustained irrigation farming, and serve as a basis for selecting lands to be included in federal irrigation projects. This designation assumes all suitable soil types and takes into account slope, present land use and other physical and economic factors. Although other areas present potential, those in Figure 32 seem most likely to offer sufficient repayment capacities to justify irrigation costs.

The recent and rapid growth of irrigated agriculture has placed a severe strain on ground water supplies, especially those of the Ogallala aquifer. Oklahoma's economy will face severe economic consequences if additional water supplies are not made available to assure continued agricultural stability.

Methodology

The methodology used in estimating Oklahoma's future water requirements was developed by the Oklahoma Comprehensive Water Planning Committee composed of representatives of the Oklahoma Water Resources Board, Bureau of Reclamation, Corps of Engineers, Soil Conservation Service, the U.S. Geological Survey and other agencies Water requirement projections for the counties of Creek, Osage and Tulsa were derived from the Tulsa Urban Study currently underway by the Corps of Engineers. These projections were developed from data provided by INCOG and the Corps, reflecting a detailed analysis of the water situation in the Tulsa area. The methodology used to derive the projections is slightly modified from that used in the Oklahoma Comprehensive Water Plan, but it was believed these projections indicated the most accurate future water demands for that area. These projections should not be interpreted as quotas or goals, but simply as forecasts based on the best information presently available. As variations from these assumptions become evident, such changes will become part of future planning efforts and subsequent revisions of this Plan.

POPULATION PROJECTIONS

Population projections utilized in the development of the Plan were provided by the Oklahoma Employment Security Commission (OESC). By combining projected births, survival of the base year population and migration of the population, the projections were derived to the year 2040.

MUNICIPAL AND DOMESTIC USE

Increasing per capita use rates (gallons per person per day) were applied to the population forecasts to determine the total municipal, domestic and rural water use projections. Historical trends were used to project increases in per capita use rates.

INDUSTRIAL REQUIREMENTS

The economic data which provided a basis for the industrial water requirement projections are disaggregates of the United States Water Resources Council's regional forecasts. Employment rates presented in these forecasts were multiplied by appropriate population projections to arrive at Oklahoma's portion of future employment by industrial activity according to Standard Industrial Classifications. Appropriate industrial water use coefficients for the Standard Industrial Classifications were applied to the employment projections to arrive at a total industrial water requirement The industrial water requirement forecast was then disaggregated to arrive at individual county projections by applying the ratios of projected county population to the total state population forecasts. Since the paper and pulp industry is relatively new in the region, little data existed on which to base projected water use, so industrial requirements for the Southeast Planning Region were increased further to allow for future growth in this water-intensive industry.

To account for future water conservation measures in Oklahoma's urban areas, it was anticipated that 15 percent of the year 2040's return flows could be recovered, but lack of public acceptance almost precludes large-scale reuse for municipal purposes. However, considering the high costs of waste treatment, it is anticipated that by the year 2040, reuse could provide about seven percent of the projected industrial, cooling water and irrigation requirements of Oklahoma's urban centers. Therefore, wastewater reuse is shown as a source of supply in the Central Planning Region and Tulsa County in the Northeast Planning Region.

IRRIGATION REQUIREMENTS

Projections of soils suitable for irrigation were developed through the joint effort of the Bureau of Reclamation and Soil Conservation Service. Although methods of the Bureau of Reclamation and the Soil Conservation Service differ slightly, both consider soil types, slopes and methods of irrigation (present and future) among other factors.

In areas where sufficient water is available, projections were on a straight-line basis. In areas requiring import water, it was assumed that such water would be available sometime between 2000 and 2040, and expected increases in irrigation were made for that period. In areas of concentrated ground water development, it was assumed that irrigation would continue to increase and that the ground water would continue to be mined It was also assumed that import water would come into use before the ground water was depleted and thereafter the amount of ground water used for irrigation would not exceed the annual recharge. Land projected for irrigation from SCS detention structures and farm ponds was also included in these projections.

Irrigation water requirements were determined by subtracting the consumptive water use for a general cropping pattern in each region from the effective precipitation, as well as allowing for losses occurring between sources of supply and the farm. It was determined that two acre-feet of water per land acre in the Northwest and Southwest Planning Regions, 1.5 acre-feet per acre in the North Central, Central and South Central Planning Regions, and 1.0 acre-feet per acre in the Northeast, East Central and Southeast Planning Regions would be required at supply sources in each region.

The potential for reuse of wastewater for irrigation was assumed to be feasible in the central Oklahoma area. Therefore, a portion of the irrigation water requirements is proposed to be met by this source.

POWER

Consumptive water use by utilities for power generation was computed at a rate of 2.5 acre-feet of water per million kilowatt hours (MKWH) of energy generated. Energy requirement estimates through the year 2040 were supplied by "Oklahoma's Energy Needs for the Future, An Interim Report."[1] As suggested in "1970 National Power Survey,"[2] the 2040 energy estimate was obtained by linear projection of 1985 and 1990 energy estimates as specified in "Oklahoma's Energy Needs for the Future." The consumptive use rate of 2.5 acre-feet of water per MKWH was applied to the projected energy requirement to determine total utility water requirements. Future power generation facilities were assumed to be developed in areas where existing facilities are presently located. Thus, utility water requirements are shown on a regional basis, rather than by individual county

OTHER USES

In addition to the requirements previously mentioned, other water uses such as recreation, fish and wildlife enhancement, low flow augmentation, navigation and water quality control are recognized. Water for these purposes is not a consumptive use, so it is therefore reusable. Thus, it was assumed that these future requirements can be fulfilled by potential reservoir development planned to meet the consumptive needs previously discussed

PROJECTED WATER REQUIREMENTS

Present water use and estimated water use projections to the year 2040 are summarized by planning region in Figure 31. The Oklahoma Comprehensive Water Plan has been developed to meet projected needs from 1990 to 2040, a 50-year planing period. Such a long period subjects forecasts to many uncertainties. However, when planning for water needs, it is necessary to assess demands as far into the future as feasible in order to maximize the return on the tremendous investment required for water development projects.

A recent study by the Bureau of Water and Environmental Resources Research (BWERR) at the University of Oklahoma developed four computer models capable of forecasting future water requirements for Oklahoma. These models – one each for municipal and domestic usage, industrial, irrigation and total water demands – are stepwise multiple regression models which utilize population, gross state product, precipitation, nonagricultural employment, total employment, bituminous coal and lignite production, per capita income, acres irrigated and land on farms as independent variables.

Projections available from these models for the years 1990 to 2040 correspond closely with projections by the Planning Committee during the initial forecasting periods. However, in the latter forecasts, the BWERR projections are substantially less than those used as a basis for the Oklahoma Comprehensive Water Plan, indicating that BWERR projections do not anticipate a growth rate as high as that assumed by the Planning Committee. If BWERR projections prove to be more accurate, the Plan simply would achieve the additional benefit of providing guidance in water planning beyond the year 2040.

WATER-RELATED PROBLEMS

Flooding

The Arkansas River Basin and the Red River Basin inflicted an estimated $167 million in flood damages on the state between 1955 and 1975, with the majority of that attibutable to the Arkansas. Immense property losses occurrd in the severe floods recorded in April through June of 1957, and in June of 1965.

Some floods occur gradually, as when prolonged steady rainfall saturates a river or stream basin until almost all of it runs off, creating a greater volume of water than the natural channels and drainage structures can carry. Others are a result of sudden, heavy rains occurring in a short time, with Oklahoma experiencing more flooding of the latter type. In either case, floods are considered a problem only when they result in widespread damage to agriculture and structures, or when the normal activities of man are seriously interrupted.

Flood damages generally are assessed within the categories of agriculture, rural, urban and transportation. Agricultural damages result in loss of crops and livestock; rural damages in erosion and destruction of fences and buildings; urban damages in loss of houses and commercial properties; transportation losses in damaged highways and bridges, and rescue and clean-up costs.

Recognizing the adverse consequences of flooding, the Soil Conservation Service and the Corps of Engineers have sought and received federal statutory authority to construct flood control and prevention structures in areas where flooding presents a threat. Under Public Law 566, the Watershed Protection and Flood Prevention Act, the Soil Conservation Service has constructed hundreds of small impoundment structures on streams throughout the state, which also serve a secondary purpose of providing a water supply source for many Oklahoma communities.

The Corps of Engineers, under the provisions of various flood control acts passed by Congress, has decreased the incidence of damaging floods through construction of extensive reservoir storage, primarily in eastern Oklahoma. The Corps is also responsible for regulating the flood control portion of reservoir projects constructed by the Bureau of Reclamation and the Grand River Dam Authority. The combined programs of the Soil Conservation Service and the Corps produce an estimated annual benefit of $180 million to the state.

Man's encroachment on a stream's natural floodplain is responsible for many flooding problems. As land has become more scarce and expensive, cities and towns have gradually encroached on flood-prone areas. Each year damages from floods cause severe economic consequences, particularly for those individual property owners, businesses and local governments which are not adequately insured.

Recognizing these dangers, the Federal Government, through the Federal Emegency Management Agency (FEMA), offers a subsidized insurance program which requires any participating local, county or state government to adopt FEMA's floodplain management criteria which limits additional development in designated floodplain areas.

Of the 466 Oklahoma communities identified as containing flood-prone areas as of December 31, 1978, 275 were participating in the federal flood insurance program. Sixteen counties in Oklahoma have been mapped and identified as containing flood-prone areas However, 15 of the 16 lack the proper authority to participate in the flood insurance program. In case of a damaging flood, cities or counties cannot qualify for federal disaster assistance unless they are participants in the National Flood Insurance Program. Many Oklahoma communities are ineligible for the subsidized insurance program due to the absence of state floodplain legislation, and therefore remain vulnerable to the heavy financial losses associated with floods.

Drought

Like other southern Great Plains states, Oklahoma has scorched under extended droughts on an approximately 20-year cycle. Notable among them were the dry years that occurred at the end of the century, again in 1910 and 1919, the dust bowl years of the 1930's, and more recently the prolonged drought of the 1950's and 1960's. Although the drought of the 1930's was the longest in Oklahoma's history, that of the 1950's was more widespread and ranked among the most destructive of the past 400 years.

An analysis of drought conditions in Oklahoma from 1931 to 1971 indicates that drought occurred somewhere in the state 51 percent of the time; more frequently in the Panhandle, and less frequently in northeast and south central areas. Eastern Oklahoma experienced short periods of drought, while the Panhandle averaged longer dry periods; again emphasizing the variability of weather in eastern Oklahoma and the normal shortage of rainfall in the west.

Drought inflicts extensive damage to agriculture, as crops burn up and livestock die from thirst. Municipalities also are adversely affected, often forced to resort to rationing programs as water supplies dwindle. Water-intensive industries often experience reduced production during water shortages, and hydroelectric power generation can be substantially cut back resulting in power shortages. Decreases in navigation storage accompanying prolonged periods of drought would necessarily have an impact on navigation on the McClellan-Kerr naviagtion system.

Although prevention of droughts is impossible, measures such as weather modification can somewhat mitigate its effect. Weather modification has evolved into a viable water resource augmentation technique. However, due to the unresolved legal and political questions surrounding weather modification, as well as its limited applicability, in this Plan it is considered as only a supplemental water source.

Upstream flood control projects such as those constructed throughout Oklahoma by the Soil Conservation Service allow the storage of water during high flows for use during dry periods. In addition to providing many communities with their sole dependable source of water, these structures also provide water for other drought caused needs.

Erosion and Sedimentation

Natural erosion and sedimentation adversely affect the quantity and quality of lakes and streams, cause the depletion of productive soils, and the deterioration of waters through the buildup of silt. When eroding soil contains residues from fertilizers or human and animal wastes, the streams and lakes become nutrient-enriched, thus enhancing eutrophication. High nutrient levels, especially nitrogen and phosphorus, result in accelerated growth of algae and other microscopic plant life, choking lakes and streams and decreasing their capacity to hold water.

Since sedimentation affects the yield of a reservoir by encroaching on conservation storage, buildup must be considered in the design of the reservoir and sediment storage provided. Periodic sediment surveys are necessary to determine the rate of accumulation, and if it exceeds design limits, might be accommodated by reallocating the remaining storage.

Sediment movement can be controlled through agronomic and mechanical practices which can typically reduce the amount of sediment reaching the reservoirs between 28 and 73 percent. Sediment yield can be reduced up to 90 percent by converting poorly suited cropland to continuous vegetation. In addition, flood-retarding structures have decreased sediment yields as much as 48 to 61 percent

Acute erosion problems have developed downstream from reservoirs generating hydroelectric power, such as those areas below Keystone Dam on the Arkansas River and Denison Dam on the Red River. These wide riverbeds consist of sand deposits and other soils which are highly susceptible to erosion. Natural stream-flows undercut the riverbanks causing caving of the banks and loss of valuable bottomland, with high streamflows resulting from flooding or generated hydropower releases greatly accelerating this process and carrying large quantities of soil, sand and silt downstream as suspended sediment.

Bank caving and erosion have caused the loss of valuable agricultural lands and crops, damaged pipelines, power lines, roads, bridges and buildings and adversely affected urban and industrial growth.

The Corps of Engineers has studied a number of methods to reduce bank caving, including low-water dams to retard downstream sediment movement, dredging channels to prevent normal flows from meandering, using stell-jetty lines and dikes, and installing stone-fill dikes and revetments.

While many of these methods are effective in controlling erosion, they are often so costly when compared to the benefits that they are not economically justified under federal criteria. Thus local interests or the state are required to provide their own means of reducing erosion.

Drainage

Problems associated with the drainage of excess water exist on approximately 5.2 million acres in Oklahoma. Drainage is the removal of excess water from the plant root zone or from surface areas where normal precipitation, seepage or excess irrigation water keeps the soil too wet for economical agricultural production. The slope of the land, permeability of the soil, depth to the water table and amount of soil aeration are the primary factors affecting drainage. The purpose of drainage is fourfold: to provide increased crop yields, to improve machinery efficiency, to achieve higher crop quality and to provide better machinery adaptability. Drainage measures include land forming to eliminate pockets, depressions and intervals; and subsurface tile drains to carry excess water to deeper channels of water courses, among others

Water Quality Degradation

The quality of Oklahoma's stream and ground water resources has emerged in recent years as a consideration of equal importance to that of quantity. Water quality is influenced by geology, climate, rural and urban development, wastewater treatment and disposal practices, storage in and diversions from lakes, and other practices applied to the operation of reservoirs. With increased discharges of wastes by municipalities, industries, and agriculture, further degradation of the waters can be expected unless adequate quality management policies are adopted.

MAN-MADE POLLUTION

Industrial development and population growth are primarily responsible for the dramatic increases in man-made pollution in recent years. Industrial discharges in excess of permit allowances burden surface waters with more than their assimilative capacities, and brine releases from oil and gas production contribute to the pollution of both stream and ground waters. New oil fields or wells may produce little or no brine, but fields nearing depletion may yield up to 100 barrels of salt water per barrel of oil.

Water-intensive coal mining operations in eastern Oklahoma produce great quantities of polluted water as a by-product. Improper disposal of this water presents serious pollution potential to the area's streams and lakes.

Municipalities often contribute damaging effluents through inadequate sewage treatment procedures. Some financially strapped smaller cities which cannot afford adequate treatment of their effluents frequently discharge excessive amounts of sulfates, sodium and other harmful elements into the state's waters. Additional treatment, primarily of a tertiary nature, will reduce such pollution but the reuse of effluent as a downstream water supply will remain a socially questionable practice.

Nonpoint sources of pollution from agricultural and urban runoff are increasing rapidly and remain difficult to identify and control. The ongoing 208 Waste Treatment Management Program will continue to investigate means of reducing or eliminating nonpoint source pollution.

Equally as endangered as surface waters are the state's fresh ground water aquifers. Oil and gas exploration activities throughout the state have adversely affected ground water supplies, while nitrate and flouride contamination threatens western Oklahoma's ground water basins. Pollution of ground water sources is particularly critical in those western areas where no alternative surface water sources are available.

Despite major strides in strengthening and enforcing Oklahoma's Water Quality Standards which determine municipal and industrial discharge limits, efforts to reduce man-made pollution of the state's stream and ground water resources must continue if the state's future water needs are to be met.

NATURAL POLLUTION

Natural mineral pollution in areas of western Oklahoma severely degrade the quality of water in the Arkansas and Red River Basins. These minerals, primarily chlorides and sulfates, often render the water of the rivers unusable for municipal, industrial, or irrigation purposes.

Streams severely degraded by chlorides include the Cimarron, Salt Fork of the Arkansas and the Arkansas River in northwestern Oklahoma; and the North Fork, Salt Fork, Elm Fork, and Prairie Dog Town Fork of the Red and the Red River in southwestern Oklahoma. The Canadian and Washita Rivers in west central Oklahoma are also polluted by sulfates originating from gypsum outcrops in their drainage areas.

Oklahoma's natural pollution problem is attributed to chlorides emitted from springs and salt flats. Fifteen such natural chloride emission areas have been identified in Texas, Kansas and Oklahoma; 10 of these in the Red River Basin, and five in the Arkansas River Basin. The extent and magnitude of the pollution problem is illustrated by the 11,900 tons of salt per day which enter Keystone Lake via the Arkansas and Cimarron Rivers and the estimated 5,400 tons per day which enter Lake Texoma on Red River.

Five of the emission zones have been identified in Oklahoma; four of them in northwestern Oklahoma in the Arkansas River Basin, and one in the Red River Basin in the southwestern corner of the state. (See Figure 25 for source locations in Oklahoma.) The four sources in the Arkansas River Basin emit an estimated 7,600 tons of chlorides per day into local streams, often raising the salt concentrations higher than that of sea water. The single southwestern source emits approximately 840 tons per day into the Red River Basin.

Extensive studies of the salinity problem by the U.S. Army Corps of Engineers have shown that the natural chloride pollution could be substantially reduced by implementing control measures at principal brine emission areas in Oklahoma and out of state.

Ground Water Depletion

Natural recharge to the underlying rock formations from precipitation and/or seepage along stream beds is very low in western Oklahoma, where ground water serves as the chief water supply source. To economically develop the agricultural resources of western areas, more water must be pumped out of the ground than is naturally flowing back into underground storage. Such mining or overdrafting of the ground water supplies threatens to deplete these vital resources within the forseeable future.

During the 1930's, few irrigation wells existed in western Oklahoma, but in the 1950's, the introduction of center pivot irrigation equipment brought extensive ground water development. The surge in irrigated agriculture resulted in declines in the water table of five to 10 feet per year As the water table declined, the amount of saturated water-bearing rock also declined, and well yields dropped. In the Panhandle, wells that had yielded as much a 1,000 gallons per minute now produce only 500 to 800 gallons per minute. The decrease in well capactiy was accompanied by greater depth to water. Water encountered at 250 feet below the surface 20 years ago now requires drilling to a depth of 350 feet or more.

To pump water from greater depths requires more fuel, and as energy costs soar, many farmers and cattlemen are unable to afford irrigation's rising costs. Although water may be available at greater depths, technological and economic restraints may prevent its use, and the aquifer can be considered effectively depleted.

Short-term alternatives to depletion include additional conservation practices and management of ground water supplies. Wells smaller in diameter and spaced at proper intervals can slow water level declines. More efficient use of water through drip irrigation, limits on annual water use by well owners and the coordination of water application with rainfall can also prolong the life of an aquifer.

Although these measures may provide a temporary solution to the problem of ground water depletion, alternative water sources will eventually be needed to supplement western Oklahoma's declining reserves.

Stream Water Availability

Due to the limitations on stream water availability imposed by lack of precipitation and runoff as well as those presented by poor water quality, there are many areas where the demand for water has reached or surpassed a stream system's capacity for supplying it.

The Oklahoma Water Resources Board has determined that all the stream water in an 8.5 million acre area illustrated in Figure 3 has been fully appropriated. Because additional development could unduly interfere with existing allocations, only minimal development of additional stream water in this area is presently possible. However, the Board continually reviews stream water permits for compliance with state law, and such review could free some water for appropriation in areas that were previously fully appropriated.

Restrictions are applicable to allocations of stream water in an additional three million acres of the state including areas on three of the state's designated scenic rivers, Big and Little Lee Creeks and the upper reaches of the Illinois River including Flint Creek. These limits are based on minimum flow criteria, and were adopted in response to increased water demands in northeastern Oklahoma to protect the rivers' scenic nature.

Reservoirs are considered fully appropriated when the Oklahoma Water Resources Board has issued water right permits equal to the yield of the reservoir. In order to protect the yield of the reservoir, applications for water rights in the drainage area above the lake can be denied or restricted. Water rights above the reservoir are issued only when it is determined that water is available in

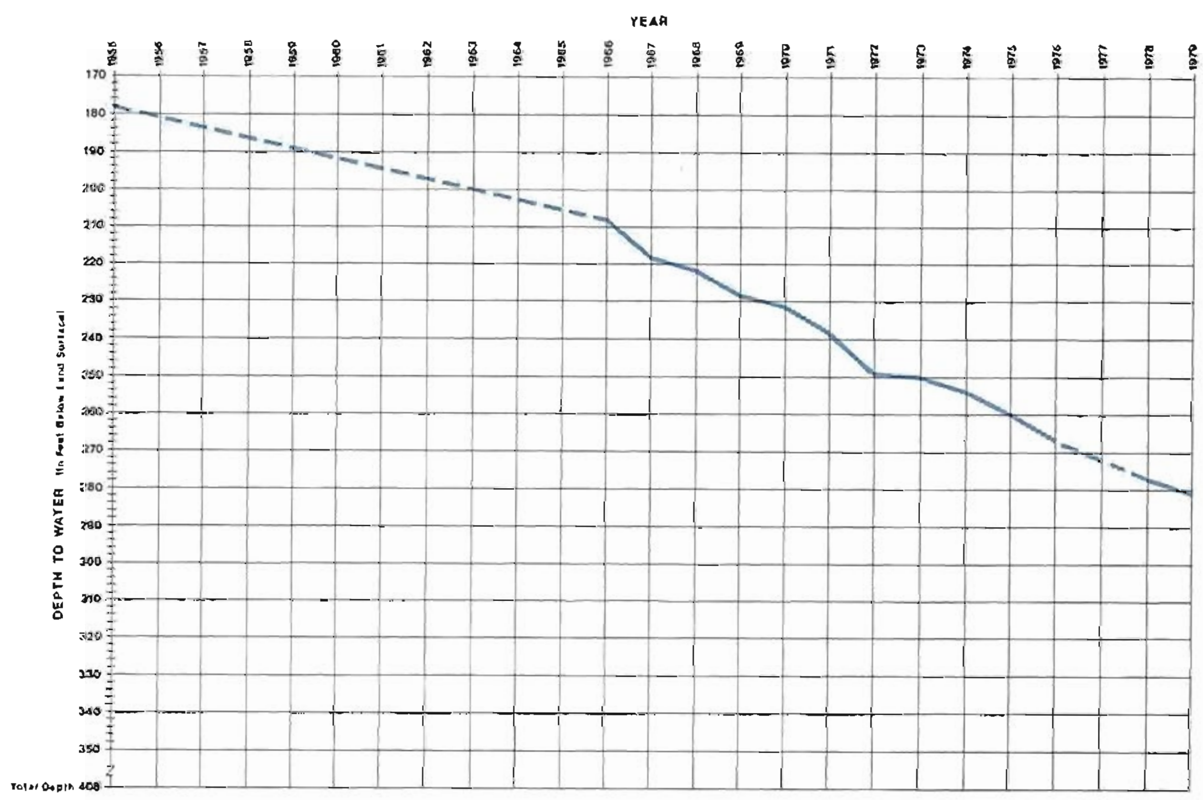


FIGURE 33 WATER LEVEL HYDROGRAPH
Well in NW ¼ NW ¼ Sec 9-T2N-R1 SE, Texas Co.

excess of the quantity necessary to maintain the reservoir yield.

Inadequate Municipal and Rural Water Systems

Approximately 200 communities across the state – mostly small towns and rural water districts -- face serious water supply problems fostered by inadequate supplies and/or poor water quality. Lack of adequate supplies, mineralized water, inadequate treatment and storage facilities and aged and deteriorating distribution systems make it impossible for these communities to maintain, much less improve, their economic viability.

A July 1977 survey indicated that some form of mandatory or voluntary water rationing was necessary in 37 communities serving 196,000 Oklahomans. Storage, treatment plants and collection systems could not keep pace with user demands, thus necessitating water rationing. Problems were so critical in some communities that sufficient fire protection was not available to the residents.

Sixty public water systems presently utilize water with chemical constituents exceeding the maximum allowable level prescribed by Oklahoma's Primary Drinking Water Standards. Concentrations of nitrate, flouride and selenium present in a majority of the systems cannot be removed by conventional treatment, but rather, require expensive treatment facilities beyond the means of small or intermediate-size cities. Many of these systems have been placed on compliance schedules to correct the violations, and will be forced to obtain new sources of supply. (See Appendix A for analyses of water supplies of rural water districts and municipalities listed by planning region.)

Current municipal indebtedness, low per capita incomes and inadequate population bases make it impossible for some communities to finance the improvements and expansions to their water supply systems required by federal and state legislation. Many lack the administrative or technical skills to perform the necessary planning and to secure financial and legal guidance.

Although there are several federal assitance programs available, low funding levels have limited participation State assistance has recently been made available through the passage of Title 82, O.S. 1979, Section 1085.31 et seq. (Senate Bill 215 of the First Session of the 37th Legislature), which authorized the Oklahoma Water Resources Board to provide financial aid to qualified cities, towns and rural water districts. Chapter VIII describes in detail the funding program available through the Oklahoma Water Resources Board.

Dam Safety

The federal legislation authorizing dam safety inspections was passed in response to the Buffalo Creek (West Virginia) dam failure in February 1972 which released flood waters that killed 125 people. Although the National Dam Safety Act was signed into law in August 1972, federal funds for its implementation were not approved until 1977, when the collapse of Teton Dam in Idaho and Toccoa Dam in Georgia again focused the attention of Congress and the public on dam safety.

Funds were made available to the states to inventory and determine hazard categories for all nonfederal dams and to conduct safety inspections of all high-hazard dams. The legislation mandated the inspection of every dam 25 feet or more in height, or with a capacity to impound 50 acre-feet or more of water.

The classification of dams by hazard potential has nothing to do with the dam's structural integrity, but with the degree of development downstream that could be adversely affected if the dam broke. It also serves to determine the priority for inspections; those appearing to possess greater hazard potential being inspected first.

As the state agency responsible for dam safety, the Oklahoma Water Resources Board is conducting an inventory which is expected to locate an estimated 4,000 dams in the state by completion of the program in 1980. Most dams in Oklahoma are earth-fill dams designed by a state-of-the-art method at the time of construction, with a potential for seepage and failure under abnormal conditions. Reductions in dam failure and mitigation of the consequences, as measured in life and property, are the major objectives of the Oklahoma Water Resources Board's dam safety program.

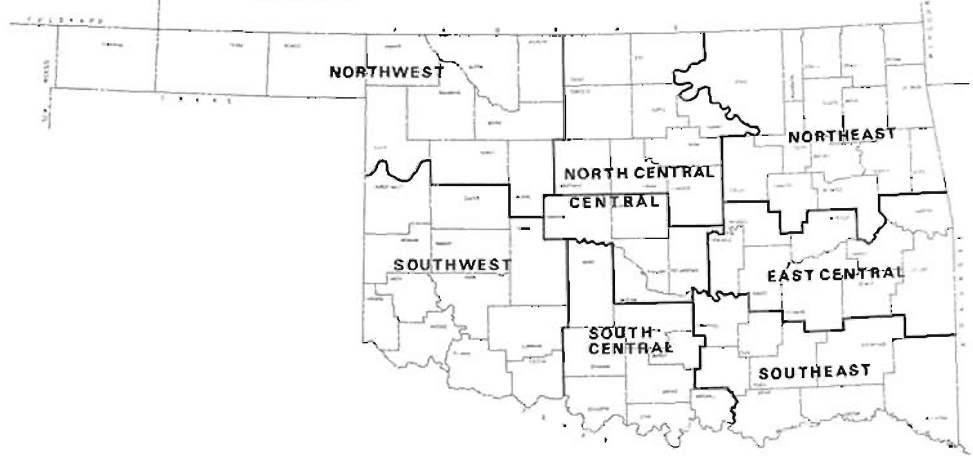
Once a dam is determined to have a high hazard potential, an inspection is required. Each inspection report contains recommendations for redesign or rebuilding, maintenance and operation, and the dam owner is required to comply with all major recommendations. To date, inventories have been performed on 1,819 structures, 112 of which were found to require corrective measures to insure the safety of those living downstream.

Although Oklahoma has not experienced a serious dam failure, the state is subject to torrential rains that can cause flooding and stress on its dams. A recent study by the National Weather Service showed that the 12-hour maximum precipitation for 10 square miles varies from 30 to 36 inches in the state. The most recent such rain occurred at Enid in 1973, when the National Weather Service measured 15.68 inches of rain in 13 hours.

An inventory of dams is never complete; new dams are built and old ones demolished. Nor is an inspection program of high-hazard dams ever finished; low-hazard dams become high-hazard and vice versa. Since present federal funding for the inventory is scheduled to end in 1980, and in 1981 for the inspection program, the question of continued funding for the state's dam safety program is crucial. If Congress fails to renew the programs through additional appropriations, the state will be required to underwrite the programs in order to insure the safety of thousands of nonfederal dams in Oklahoma.

CHAPTER V
PLANNING REGION ANALYSES

FIGURE 34 PLANNING REGIONS



The scope and magnitude of the Oklahoma Comprehensive Water Plan defy considering the entire state as a single unit for the purpose of meaningful long-range water planning, yet Oklahoma's 77 counties represent fragments too small for the preparation of any plan of a comprehensive nature. Therefore, at the inception of the Board's work on Oklahoma's Comprehensive Water Plan, the state was divided into the eight planning regions shown in Figure 34 . The counties grouped in each region exhibit certain common characteristics, including homogeneity of climate, geography, hydrology, economics and demography, that meld them into functional planning units.

At the same time, the multi-county regions are unique in their water-related characteristics, varying one from another in their water resources and requirements. Planning on a regional basis permits the evaluation of these unique characteristics in the design of appropriate local water development plans.

The ground water and stream water resources of each region were inventoried to determine existing and potential water resource development capabilities. Water requirements were projected in order to forecast municipal, industrial, utility (power) and irrigation needs of each region. Projected water requirements were then compared with the local water development potential, and a local development plan based on potential development was formulated.

This chapter contains an analysis of each of the eight planning regions, including proposed Regional Plans of Development and costs for their implementation.

The proposed Regional Plans of Development offer a means of meeting all or part of the regions' projected water requirements through the year 2040. The plans have been prepared to optimize the potential water resources development within each region. In several regions, sufficient local supplies have not been identified for development capable of meeting future needs, therefore, these regions will require water from outside the local area if they are not to suffer from expected water deficits.

Cost estimates for the proposed Regional Plans of Development are shown in Figure 35 . Based upon January 1978 price levels, the total cost of regional development could approach $3 billion. Estimates were prepared with assistance from the Bureau of Reclamation, Corps of Engineers and Soil Conservation Service. The costs are not of a final nature, but rather should be used to comprehend the financial requirements necessary to implement the local plans.

A benefit analysis has not been prepared for any of the proposed projects. Additional studies would be required on each proposed project to determine their economic feasibility under federal guidelines, as well as the amount of state or local contributions that might be necessary.

The plans proposed should be considered a flexible guide for each reigon, subject to change; not as a hard and fast blueprint for action. Alternative projects within each region would be appropriate so long as they are compatible with the overall policies and guidelines of the Oklahoma Comprehensive Water Plan.

FIGURE 35 SUMMARY OF COSTS[1] PROPOSED REGIONAL PLANS OF DEVELOPMENT (In $1,000)

REGION	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[3]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[4]
Southeast[2]	$ 289,800	$ 4,010	$ 15,335
Central	123,370	935	9,225
South Central	321,915	1,845	21,528
Southwest	270,130	1,740	17,115
East Central[2]	243,820	4,642	18,540
Northeast[2]	374,940	14,484	41,320
North Central	839,080	4,925	66,210
Northwest	288,830	1,544	19,825
TOTAL	$2,751,885	$34,125	$209,098

[1]Based on January 1978 prices.

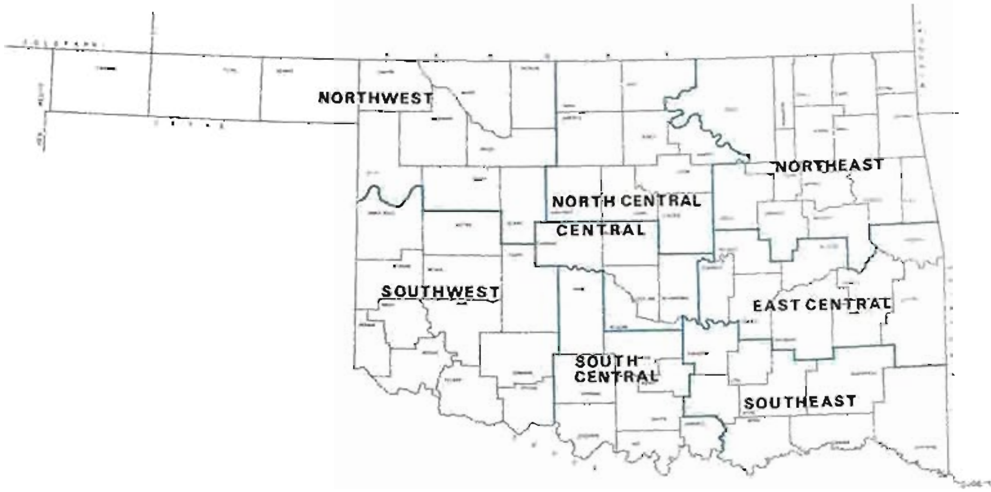
[2]Mitigation/compensation costs not completed for these regions at this time.

[3]Energy costs computed at a 30-mil power rate.

[4]Includes interest and amortization, as well as average annual OMR&E.

SOUTHEAST PLANNING REGION

The 8-county Southeast Planning Region covers 7,919 square miles, encompassing Atoka, Bryan, Choctaw, Coal, Johnston, McCurtain, Pontotoc and Pushmataha Counties.



The mining of coal in the 1870's and the first drilling for oil near the City of Atoka mark the earliest development of natural mineral resources in the state. Vast timber and water resources also distinguish this region.

The northern part of the region is characterized by rugged hills and mountains, smoothing the gently rolling plains, then leveling to the alluvial plain where it meets the Red River in the south. Elevations range from over 2,500 feet in the north to approximately 300 feet in the southeast. The region is drained by the Red River and its tributaries: the Blue, Kiamichi, Mountain Fork and Little Rivers; and Clear Boggy Creek.

Population statistics compiled in 1977 show this 8-county region at 144,000, an increase of 10 percent since 1970. This rise is equivalent to the 7-year increase for the state as a whole, demonstrating the healthy growth of the area. During the same period, per capita personal income (before taxes) increased from $2,040 to $4,100. The region is further characterized by a high percentage of employment in the sectors of wholesale and retail trade, manufacturing and construction.

Population in the Southeast Planning Region consists of 62 percent rural and 38 percent urban residents. Major population centers include Poteau, Idabel, Durant and Hugo.

The economic condition of the region is strong with opportunities available in a number of dependable fields. An occupational potential inventory in 1978 shows clerical, sales and service fields to be highly promising. With an abundance of natural resources and a growing population, the economic outlook for this area is bright.

The southeast region lies in a moist, subhumid climate where annual precipitation and evaporation levels are virtually equal. Although precipitation is normally distributed evenly throughout the year, droughts of short duration are fairly frequent during the 8-month growing season. In summer, under the influence of prevailing southerly winds bearing moisture from the Gulf of Mexico, a favorable atmosphere for thunderstorms exists. Occasionally, westerly or northerly winds introduce hotter and drier air. During the winter months winds over the region can alternate between tropical and polar air masses, bringing sudden drops in temperature.

As shown in Figure 8 , average annual precipitation ranges from 40 inches in the west to 56 inches in the east, with the heaviest rainfall occurring in northern McCurtain County over the Little River and Kiamichi River watersheds. The region receives approximately six inches of snowfall annually. The average lake evaporation east to west across the region varies from 48 to 56 inches, as shown in Figure 9 . This amount is low in comparision to that of western Oklahoma, and is due to the lack of sustained high velocity winds during the hot summer months. High rainfall and low evaporation rates present a climate favorable to the construction of reservoirs, as evidenced by the region's many lakes and impoundment structures.

Mean annual temperature in the region ranges from 62° F in the north to 64° F in the south. The maximum temperature recorded was 118° at Hugo in August 1936, and the minimum, -22° at Smithville in February 1951.

The length of the growing season, which is defined as the period between the average date of the last 32° temperature in the spring and the average date of the first 32° temperature in the fall, averages 240 days.

The large amounts of precipitation and runoff in this region foster frequent damaging floods such as those recorded on the Kiamichi near Belzoni in October 1915, with a maximum discharge of 72,000 cfs; on Little River near Wright City in 1951, with a 78,200 cfs discharge; and on Mountain Fork River near Eagleton in 1969, with a maximum discharge of 101,000 cfs.

Twice within an 11-month period, on December 10, 1971 and again on October 31, 1972, Glover Creek and Little River overran their banks and caused devastating floods. The gaging station at Glover, Oklahoma recorded discharge rates of 98,000 cfs and 86,300 cfs respectively for these floods, and according to local residents, the 1971 flood inundated 60,000 acres of land, causing damages in excess of $17.5 million. The 1972 flood covered an estimated 30,000 to 40,000 acres and caused $12.6 million in damages in McCurtain County.

In 1973, moderate flooding occurred on the Red River and Blue River and on Clear Boggy and Muddy Boggy Creeks. Again in October and

November of 1974, these streams experienced serious flooding, with the Blue River at Blue rising almost 11 feet above flood stage and the Clear Boggy and Caney registering 4.6 feet of flooding. High flows from these and other tributaries of the Red combined with heavy rains areawide and caused flooding downstream around DeKalb, Texas which inflictd $115,000 in losses to soybeans, hay and cattle.

Following two dry years, during which Texoma Reservoir dropped as much as eight feet below normal pool elevation, heavy rainfalls returned in March of 1977, deluging the basin with 10 inches. As a result of a 6-inch rainfall in six hours, Blue River at Blue crested nearly 13 feet over flood stage, and 20 people fled their homes in Durant as flash flooding struck Mineral Bayou, a Blue River tributary.

Extensive work on watershed protection and flood prevention on the Boggy River has been accomplished by the Soil Conservation Service, and many additional sites are planned to further relieve flooding problems. The Corps of Engineers has reduced the severity of flooding by providing flood storages in the remainder of the Red River Basin below Denison Dam.

WATER RESOURCES

Stream Water

Stream Water is readily available in large quantities throughout the region. The high rate of precipitation and naturally rough, steep terrain lend themselves to the production of substantial amounts of water within comparatively small drainage areas. Through the efforts of the Corps of Engineers, Bureau of Reclamation, Soil Conservation Service and various state and local entities, numerous lakes have been planned and developed to make stream water available for beneficial uses. There are many potential reservoir sites available as the future beneficial needs of this region and the state increase.

Average annual runoff from precipitation and springs is about 15 inches, ranging from six inches in Pontotoc County to 20 inches in the northeast corner of McCurtain County, for a total originating within the region of six million acre-feet per year. Of this amount, 2,804,000 acre-feet flow into the Red River within Oklahoma.

The United States Geological Survey maintains nine gaging stations on streams in the southeast region. Metering devices compile stream data used in determining the amount of water available for storage at a given site and the effect of such impoundment structures on downstream flows.

A summary of stream flows at selected USGS gaging stations is included in Appendix B, Figure 2.

Red River (main stem) water quality is rendered inferior by a high total dissolved solids content, a result of natural salt pollution upstream. Water quality improves farther downstream as high quality stream flows from tributaries below Denison Dam enter the Red River. Municipal and industrial use of water from the Red River is restricted by quality limitations. Irrigation use is restricted in the upper reaches, but improved quality downstream makes the water usable for irrigation of certain crops.

The lower reaches of the Red are characterized as being moderately turbid, exhibiting high levels of iron and manganese. Dissolved oxygen depletions occur directly below Denison Dam during the warmest months, but downstream recovery is rather rapid.

The Little River is a high quality stream with low mineralization and enrichment. The stream has low turbidity and very soft water, and metals toxicity is not a problem.

Glover Creek has good water quality with nutrient and mineral indices indicating minimal mineralization and low nutrient levels. The stream exhibits very little turbidity of hardness, and dissolved oxygen remains at saturation levels throughout the year.

Mountain Fork River has no known point source discharges, so the insignificant pollution that exists is assumed to be attributable to nonpoint sources. It is a high quality stream with little mineralization and low nutrient levels. There has been no evidence of degradation trends to date, and toxic metals remain at very low levels throughout the stream's length.

Kiamichi River is a high quality stream with low to moderate turbidity, soft water and low mineralization. The river has generally low nutrient enrichment. Iron and manganese frequently exceed standards, but toxic metals are not present in elevated levels.

Clear Boggy Creek is a fairly turbid stream with dissolved oxygen usually remaining near saturation levels. Water quality is good with low mineralization and nutrient levels.

Muddy Boggy Creek is a very turbid stream with good water quality and exhibiting fair nutrient levels and low mineralization. The stream has very soft water, and its dissolved oxygen content consistently registers near saturation levels.

Blue River waters show very good quality, and mineralization and nutrient concentrations remain low. The river has hard water, and registers dissolved oxygen at levels close to saturation. The water is somewhat turbid most of the year in the lower reaches of the river.

Water quality analyses data for selected USGS monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5.

STREAM WATER DEVELOPMENT

The Southeast Planning Region is more richly endowed with rainfall and good quality streams than any other part of the state, an advantage contributing to the region's extensive development of stream water resources. There are three existing federal lakes: Broken Bow, Hugo and Pine Creek; two additional federal lakes under construction: Clayton and McGee Creek; and one major municipal lake: Atoka. These lakes have a combined water supply storage capacity of 875,000 acre-feet for municipal and industrial purposes

Major Reservoirs

Authorized purposes of the five federal projects include water supply, flood control, water quality control, recreation, fish and wildlife propagation and hydroelectric power generation.

Broken Bow Lake is located on the Mountain Fork River in McCurtain County, with the dam located about 10 miles north of the town of Broken Bow in the Kiamichi Mountains. The lake is a unit in the 7-reservoir system planned for flood control in the Little River watershed. The dam is the highest earthfill structure in Oklahoma, having a crest length of 2,820 feet and rising to a maximum height of 225 feet above the streambed.

There are 317,600 acre-feet of hydroelectric power generation storage, converted to energy by two 50,000 kw generating units.

Mountain Fork River exhibits water of excellent quality, making Broken Bow Lake water appropriate for any beneficial use. Since impoundment of the lake, the water supply storage has not been utilized other than for recreation and hydroelectric power generation purposes. The entire water supply yield of 196,000 acre-feet per year is available for appropriation.

Hugo Lake is located on the Kiamichi River about seven miles east of Hugo in Choctaw County. Along with Clayton Lake, under construction, and authorized Tuskahoma Lake, it comprises a 3-lake system proposed within the Kiamichi River Basin. Upon completion of Clayton and Tuskahoma Reservoirs upstream, conversion of flood control to water supply in Hugo Lake could raise the ultimate dependable yield of the reservoir to 302,800 acre-feet annually.

Water impounded in Hugo Lake is of high quality, classifying as suitable for municipal and industrial uses. The Cities of Hugo and Antlers are the only current users of this water. Western Farmers Electric Cooperative is currently building a new generating facility, and has contracts pending for storage in the lake. Water is available for additional appropriations.

Pine Creek Lake is located on Little River approximately five miles northwest of Wright City in McCurtain County.

The 70,500 acre-feet of conservation storage will supply a dependable yield of 134,400 acre-feet from the combined water supply and water quality control storages.

Water quality of Pine Creek Lake is excellent, suitable for any beneficial purpose. Presently the Weyerhaeuser Company is the only user, so some of the water supply yield remains available for appropriation.

Clayton Lake is located on Jackfork Creek, one of the main tributaries of the Kiamichi River, and lies 2½ miles north of Clayton and five miles northwest of Tuskahoma in Pushmataha and Latimer Counties. Construction of the embankment and outlet works was begun in September 1977, with an expected completion date in 1981. The project is approximately 60 percent complete.

Water quality is good except for the presence of iron, which from time to time exceeds the recommended limit of 0.3 ppm. Removal of iron in the amounts anticipated is neither difficult nor costly.

Before the Corps of Engineers could begin construction of Clayton Lake, contracts to repay the costs allocated for water supply storage in the lake had to be approved. Because no local water-using entity was capable of obligating the funds necessary to enter into the contract, the Oklahoma Water Conservation Storage Commission signed the required contract in 1974, facilitating construction of the lake development. The entire water supply yield of Clayton Lake is available for appropriation.

McGee Creek Reservoir is under construction on McGee Creek, a major tributary of the Muddy Boggy, about three miles north of Farris and 18 miles southeast of Atoka.

Dependable water supply yield from the reservoir will be 71,800 acre-feet of water of very good quality. Water rights encompassing this yield have been allocated as follows: 40,000 acre-feet to Oklahoma City; 8,000 acre-feet to the City of Atoka; 8,000 acre-feet to Atoka County; 4,000 acre-feet to the Southern Oklahoma Development Association;

FIGURE 36 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Atoka Lake	North Boggy Creek	WS, R	0	123,500	1,224[1]
Broken Bow Lake	Mountain Fork River	WS, FC, P, R, FW, WQ	450,000	152,500[2]	196,000[2]
Clayton Lake +	Jack Fork Creek	WS, FC, R, FW	128,200	297,200	156,800
Hugo Lake	Kiamichi River	WS, FC, WQ, R, FW	809,100	121,500[3]	165,800[3]
McGee Creek Lake +	McGee Creek	WS, FC, R	86,000	109,800	31,800[4]
Pine Creek Lake	Little River	WS, FC, WQ, FW	388,100	70,500[5]	134,400[5]
SUBTOTAL			1,861,400	875,000	686,024

(Continued)

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		AUTHORIZED			
Boswell Lake	Boggy Creek	WS, FC, R, FW	1,096,000	1,243,800	621,400
Hugo Lake ultimate development	Kiamichi River	WS, FC, WQ, R, FW	651,800	284,300	137,000[6]
Lukfata Lake	Glover Creek	WS, FC, R, FW	208,600	37,500[7]	59,400[7]
Tuskahoma Lake	Kiamichi River	WS, FC, R, FW	138,600	231,000	224,000
SUBTOTAL			2,095,000	1,796,600	1,041,800
TOTAL			3,956,400	2,671,600	1,727,824
		POTENTIAL			
				CONSERVATION STORAGE	
Ada	Sandy Creek	WS, R	0	115,000	23,500
Albany	Island Bayou	WS, FC, R	55,100	85,200	35,800
Broken Bow reregulation structure[8]	Mountain Fork River		—	—	289,000[8]
Buck Creek	Buck Creek	WS, FC, R	36,300	48,300	56,000
Caney Mountain	Little River	WS, FC, R	105,100	530,000	280,000
Chickasaw	Chickasaw Creek	WS, FC, R	22,000	36,000	17,900
Durant	Blue River	WS, FC, R	232,200	147,000	134,400
Finley	Cedar Creek	WS, FC, R	63,300	210,600	95,200
Kellond	Ten Mile Creek	WS, FC, R	43,300	133,000	56,000
Lukfata Modification	Glover Creek		—	—	175,800[9]
Parker	Muddy Boggy Creek	WS, FC, R	115,400	114,650	47,000
Ravia	Mill Creek	WS, R, FW	0	45,000	19,000
Tupelo	Clear Boggy Creek	WS, FC, R, FW, I	177,300	302,550	100,800
TOTAL			850,000	1,767,300	1,330,400
TOTAL YIELD					3,058,224

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage than can be economically justified as a project purpose.

+Under Construction

[1]Total yield of Atoka Lake is 65,000 acre-feet per year. The 1,224 acre-feet per year yield shown above is allocated to the southeast region. The other 63,776 acre-feet per year is allocated to Oklahoma City in the central region.

[2]Includes water quality control storage of 95,000 acre-feet which yields 123,200 acre-feet per year. Broken Bow Lake also has 317,600 acre-feet of hydroelectric power storage.

[3]Includes water quality control storage of 74,000 acre-feet which yields 100,800 acre-feet per year.

[4]Total yield of McGee Creek is 71,800 acre-feet per year. The 31,800 acre-feet per year yield shown above is allocated to the southeast region. The remaining 40,000 acre-feet per year is allocated to Oklahoma City in the central region.

[5]Includes water quality control storage of 21,100 acre-feet which yields 49,320 acre-feet per year.

[6]Potential additional yield after Clayton and Tuskamona are constructed.

[7]Yield at original authorized dam site includes 13,230 acre-feet for fishery mitigation and recreation which yields 22,400 acre-feet per year.

[8]This is the approximate yield that could be developed from hydropower releases from Broken Bow.

[9]Additional yield with modification at recently considered downstream dam site.

8,000 acre-feet for downstream releases, and 3,800 acre-feet reserved for future needs. Water allocated to Oklahoma City will be transported to Lake Stanley Draper via Lake Atoka through the existing Atoka pipeline.

Funding for the Bureau of Reclamation to begin land acquisition was approved by Congress for FY 1980. Completion time of the project is expected to be four to five years.

Major Municipal Lakes

Atoka Lake, on North Boggy Creek four miles north of the City of Atoka, serves as a major water supply source for Oklahoma City, the water being transported out of basin by a 60-inch pipeline to Lake Stanley Draper in southeast Oklahoma City. Built in 1964 by the City of Oklahoma City, the pipeline initially had a 60 mgd capacity, but a recent $10 million modification increased the capacity to 90 mgd to meet the city's escalating water needs. The lake also provides water supply to the City of Atoka.

Upon completion of McGee Creek Reservoir, Atoka Lake will receive water from that reservoir for subsequent further transfer via the existing pipeline to Oklahoma City. The water is of very good quality.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered construction of a number of flood control structures in the Southeast Planning Region in conjunction with its watershed programs. Although primary emphasis in on protection of watershed drainage areas and reduction of floods in productive bottomlands, in recent years increased emphasis has been placed on multipurpose structures to provide storage for municipal, irrigation and recreation uses.

The City of Coalgate is presently using a Soil Conservation Service multipurpose flood control structure as a source of water supply. Potential SCS multipurpose sites are also being considered for development by the Cities of Durant and Antlers.

Authorized Development

There are three reservoirs authorized for construction by the Corps of Engineers in the southeast region.

Boswell Lake is authorized for construction on Boggy Creek, three miles west of Soper in Choctaw County. The project is authorized to include 1,096,000 acre-feet of flood control storage. Dependable water supply yield is estimated at 621,400 acre-feet per year.

The quality of water to be impounded in Boswell Lake is rated good and, although hard, it will be suitable for municipal and most industrial purposes.

Lukfata Lake is authorized for construction on Glover Creek, approximately 13⅓ miles north of Glover in McCurtain County. It will provide water of excellent quality.

In 1977 the Lukfata project was jeopardized by the discovery of the Leopard Darter, a fish species classified as a threatened species, and it was determined that the project would adversely affect the Darter's habitat. As a result, Congress withdrew construction funds and the project remains inactive.

Tuskahoma Lake is authorized for construction on the Kiamichi River in Pushmataha and LeFlore Counties. The dam site is located one mile south of the town of Albion. Water proposed for impoundment is of high quality and suitable for general municipal and industrial purposes.

Potential Development

The high rate of precipitation and the abundance of geographically suitable dam sites make the southeast region appropriate for extensive water resource development. Although a virtually unlimited number of potential dam sites exists, those listed in Figure offer the greatest potential for multipurpose development. The studies that provided the bases for their selection ranged in complexity from simple appraisals or preliminary local assessments to larger and more comprehensive feasibility level investigations.

STREAM WATER RIGHTS

As of February 20, 1979, there had been issued 560 vested stream water rights and permits for the appropriation of 812,820 acre-feet of water per year from the rivers, streams and lakes in the Southeast Planning Region. The totals by county and by use are shown in Figure 37 .

Ground Water

Several major ground water basins exist within the boundaries of the Southeast Planning Region. The rock units that comprise these major basins are the Arbuckle Group, sandstones of the Simpson Group, Antlers Sandstone and various alluvium and terrace deposits. The locations of these formations are shown in Figure 28 .

Ground water resources supply moderate quantities of water for domestic, municipal, industrial and irrigation uses.

Arbuckle Group (Cambrian-Ordovician) consists of broad areas of limestone and dolomite exposed over a 200-square mile area in southwestern Pontotoc and northwestern Johnston Counties. The several thousand feet of limestone and dolomite show high permeability resulting from fractures, joints and solution channels formed in the rocks, conditions causing the accumulation and circulation of large quantities of water. Depth to water ranges from 50 feet to more than 100 feet, but generally is less than 100 feet. Well yields are commonly 200 to 500 gpm and as great as 2,500 gpm.

Although hard and of the calcium bicarbonate type, the water is suitable for most purposes because of its low content of dissolved solids, consisting mainly of sulfates and chlorides.

Present development is sparse, but this basin offers a major potential source of water.

Simpson Group (Ordovician) is a series of sandstone beds totaling 300

FIGURE 37 STREAM WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Atoka	9	186,188	2	12,000	38	9,556	—	—	—	—	2	216	51	207,960
Bryan	4	8,500	1	17	128	50,042	1	2,820	1	500	1	7,000	136	68,879
Choctaw	3	80,500	1	32,000	47	32,380	—	—	—	—	2	290	53	145,170
Coal	2	1,645	3	447	21	2,198	—	—	—	—	—	—	26	4,290
Johnston	3	2,746	3	55	58	62,405	—	—	1	25	1	1,845	66	67,076
McCurtain	7	51,464	5	95,703	80	34,125	—	—	2	16,025	3	370	97	197,687
Pontotoc	1	3,358	2	7,077	35	10,278	—	—	1	23	1	60	40	20,796
Pushmataha	5	7,825	—	—	82	16,816	—	—	—	—	4	3,681	91	28,322
Total	34	342,226	17	147,298	489	217,800	1	2,820	5	16,573	14	13,462	560	740,180

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use, and are subject to reduction or cancellation from continued non-use. The data indicate prevalent trends of beneficial water use by county and region.

feet in thickness and cropping out in a 60-square mile area of northeastern Johnston County and smaller areas in central and southeastern Pontotoc County. The sandstone is fine grained and loosely cemented, yielding water freely to wells. Most wells are shallow, with an estimated depth to water of 400 feet. However, southwest of Ada, wells tap the sandstones at a depth of 1,600 feet. Yields are 125 to 500 gpm, averaging 200 gpm. Quality of water is potable in the outcrop area, but deteriorates downdip from the outcrop. Due to its small areal extent, this ground water basin is not as significant as the Arbuckle Group.

Antlers Sandstone (Cretaceous) is part of the large coastal plain deposits which crop out in the southern half of the region. The Antlers Aquifer, which consists of up to 900 feet of friable sandstone, silt, clay and shale, crops out in a 1,500-square mile area in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties. It underlies about 3,500 square miles. Precipitation ranges from 34 to 50 inches per year across the outcrop area, which is receptive to high rates of infiltration. The average saturated thickness of the sand is 250 feet.

Aquifer tests indicate the average transmissivity is 1,480 feet per day and the average storage coefficient is 0.0005. High capacity wells tapping the aquifer commonly yield 100 to 500 gpm, with the maximum yield having been measured at 1,700 gpm. Little water is used from the aquifer because of the abundance of surface water in the area.

Actual recharge rates are estimated to be approximately six inches per year, representing about 15 percent of the average annual precipitation of 42 inches. The total annual recharge to the aquifer from precipitation is an estimated 480,000 acre-feet of water.

Water in the Antlers Aquifer in Oklahoma is discharged naturally through springs and seeps, evaporation, transpiration by plants, underflow out of Oklahoma to the south and southeast and, in the artesian portion of the reservoir, by upward movement of water through less permeable confining strata.

Water is discharged artificially by pumpage and by flowing artesian wells. In 1975 estimated ground water withdrawals from the aquifer totaled 7,000 acre-feet.

Water quality throughout the central and northern part of the aquifer is generally acceptable for municipal use. A few wells, however, yield water containing concentrations of iron and manganese exceeding the recommended limits. In general, water quality tends to degrade downdip. In some areas water in the upper part of the aquifer contains less than 1,000 mg/L dissolved solids, while water in the lower part contains somewhat more.

Water from the Antlers Aquifer varies in its chemical composition, usually being of the sodium bicarbonate type in the outcrop area, although in isolated areas immediately downdip, it may be of the calcium sulfate or calcium bicarbonate type. As the water moves further downdip, it changes to a sodium chloride type. Based on the analyses available, most of the wells yield water with a dissolved solids concentration of less than 500 mg/L

GROUND WATER DEVELOPMENT

Ground water is an abundant natural resource in the region and present development could be greatly expanded. However, certain factors do present constraints: small areal extent of the basins (with the exception of the Antlers Sandstone); topography unfavorable to irrigation; lack of data concerning hydraulic characteristics of the basins; and lack of water quality information such as locations of fresh water/salt water interface zones.

Use of ground water for municipal, industrial and rural purposes can be expected to increase because southeastern Oklahoma is rapidly attracting industries that require moderate quantities of good quality water. Because large amounts of precipitation fall in the area, demand for irrigation water will probably remain limited. Rural water usage may increase rapidly as industry develops, but rural wells will be widely spaced, pumping for short periods at rates of five to 10 gpm, and recharge from precipitation should nullify most of the effects of pumping.

Ground water development has occurred predominantly in two of the four major basins, the alluvium and terrace deposits and the Antlers Sandstone. Of the 221 municipal, industrial and irrigation wells in the region, 111 are in the alluvium and terrace deposits. The area most favorable for the development of wells is along the Red River, where wells commonly yield several hundred gallons per minute. The most productive sites are those in areas with the greatest saturated thickness and the coarsest material.

The Antlers Sandstone, second in importance of development, has 89 municipal, industrial and irrigation wells in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties producing yields of a few gallons per minute to more than 650 gpm. The Arbuckle and Simpson Group ground water basins have experienced only sparce development, with 21 municipal, industrial and irrigation wells recorded, although well yields often exceed 200 gpm.

FIGURE 39 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	16.5	21.0	24.4	29.1	32.3	37.4	56.1
Industrial	71.3	88.7	103.6	119.8	137.4	154.9	172.2
Power	—	10.7	16.2	21.6	27.1	32.6	38.0
Irrigation	13.9	46.9	94.3	141.1	188.2	235.5	282.4
Total	101.7	167.3	238.5	311.6	385.0	460.4	548.7

GROUND WATER RIGHTS

As of July 1979, a total of 115 ground water permits had been issued in the region for the appropriation of 53,907 acre-feet of water per year. These permits allocate ground water for municipal, industrial, irrigation, secondary oil recovery and commercial purposes.

Data from the ground water rights files of the Oklahoma Water Resources Board are shown in Figure 38. Prior rights have not yet been determined for any county in the Southeast Planning Region.

PRESENT WATER USE AND FUTURE REQUIREMENTS

Current water requirements for the Southeast Planning Region are estimated to be 101,700 acre-feet per year with over half of this amount being used for industrial purposes. The primary industrial user is the Weyerhauser Company, a paper and pulp processing firm in McCurtain County which operates three plants employing 1,771 persons. Irrigation is the next largest user, with municipal use ranking third.

Municipal water projections, which include rural water needs, indicate that the southeast region will require 56,100 acre-feet annually by the year 2040, an increase of over two and one-half times the present use of 16,500 acre-feet. The Cities of Ada, Durant, Hugo and Idabel will probably consume most of this increase, as they are expected to lead the planning region to a total population growth of over 250,000 by the year 2040.

There are 49 rural water districts in the region serving an estimated 40,000 people. Increasing water demands of small towns and rural areas are expected to require expansion of existing systems and the formation of new districts. By the year

FIGURE 38 GROUND WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Atoka	3	634	—	—	—	—	—	—	—	—	—	—	3	634
Bryan	7	4,579	—	—	24	5,088	—	—	1	50	1	10	33	9,727
Choctaw	4	3,440	1	1,240	4	1,300	—	—	—	—	1	60	10	9,020
Coal	2	95	—	—	1	500	—	—	1	160	—	—	4	755
Johnston	5	874	1	703	9	3,521	—	—	2	100	—	—	17	5,198
McCurtain	3	392	1	160	2	390	—	—	—	—	—	—	6	942
Pontotoc	5	12,318	3	7,425	30	5,170	2	2,600	1	20	—	—	41	27,533
Pushmataha	—	—	—	—	1	100	—	—	—	—	—	—	1	100
Total	29	22,332	6	10,708	71	17,869	2	2,600	5	330	2	70	115	53,909

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

2040, almost 70,000 citizens will be served by rural water districts in this planning region.

Industrial water requirements are presently 71,300 acre-feet annually. The region's abundance of water and other natural resources continue to attract new industries which could drive 2040 projected water demands up to 172,200 acre-feet annually. The largest industrial users in the region are firms involved in pulp and paper processing as well as meat processing and packaging.

Although there are no existing demands for water for power purposes, a steam powered electric generating plant is currently under construction near Hugo which will require water for cooling purposes. The 400 megawatt plant being built by Western Farmers Electric Cooperative is scheduled for completion by April, 1982. The plant will have a gross annual water usage of 8,400 acre-feet (7.5 mgd) of water from Hugo Lake with a discharge of 1,344 acre-feet per year (1.2 mgd) for a consumptive use of 7,056 acre-feet per year (6.3 mgd). Total cooling water for power generation in the region is projected to be 38,000 acre-feet annually by 2040.

A 1977 Irrigation Survey by the Oklahoma State University Cooperative Extension Service indicated there were 182 farms encompassing 21,488 irrigated acres in the region. Present estimated use is 13,900 acre-feet per year and projections indicate that 282,400 acres requiring 282,400 acre-feet of water may be irrigated by the year 2040. With the region's abundant rainfall, irrigation will only be used as a supplemental supply.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Abundant rainfall and runoff provide the Southeast Planning Region with the potential for extensive water resources development. Consequently, the 8-county area currently has three major reservoirs and two additional reservoirs under construction, making great amounts of good quality water available. However, much of the area suffers inadequate distribution problems which limit potential economic development and periodic flooding throughout the region endangers human lives and threatens property destruction. To meet the region's future water needs, efforts should be directed toward controlling the region's flood-waters and developing local water supplies.

Existing ground and stream water sources can supply approximately 102,000 acre-feet per year and proposed local sources could provide the additional water to meet the region's projected 2040 water requirements with an annual surplus of approximately 1.6 million acre-feet. Other stream water sources not included in the local plan could provide an additional two million acre-feet, achieving a total potential annual surplus of over 3.5 million acre-feet. (See Figure 40.)

The Oklahoma Comprehensive Water Plan proposes a regional plan of development which includes utilization of existing sources, development of new reservoirs and increased usage of available ground water supplies, as well as construction of appropriate municipal, industrial and irrigation distribution facilities. (See Figure 41.) Existing Broken Bow, Hugo and Pine Creek Lakes have excellent quality water available for beneficial use, however, water supply storage in these lakes is presently used only sparingly. With the construction of pertinent distribution facilities or trunk lines, these

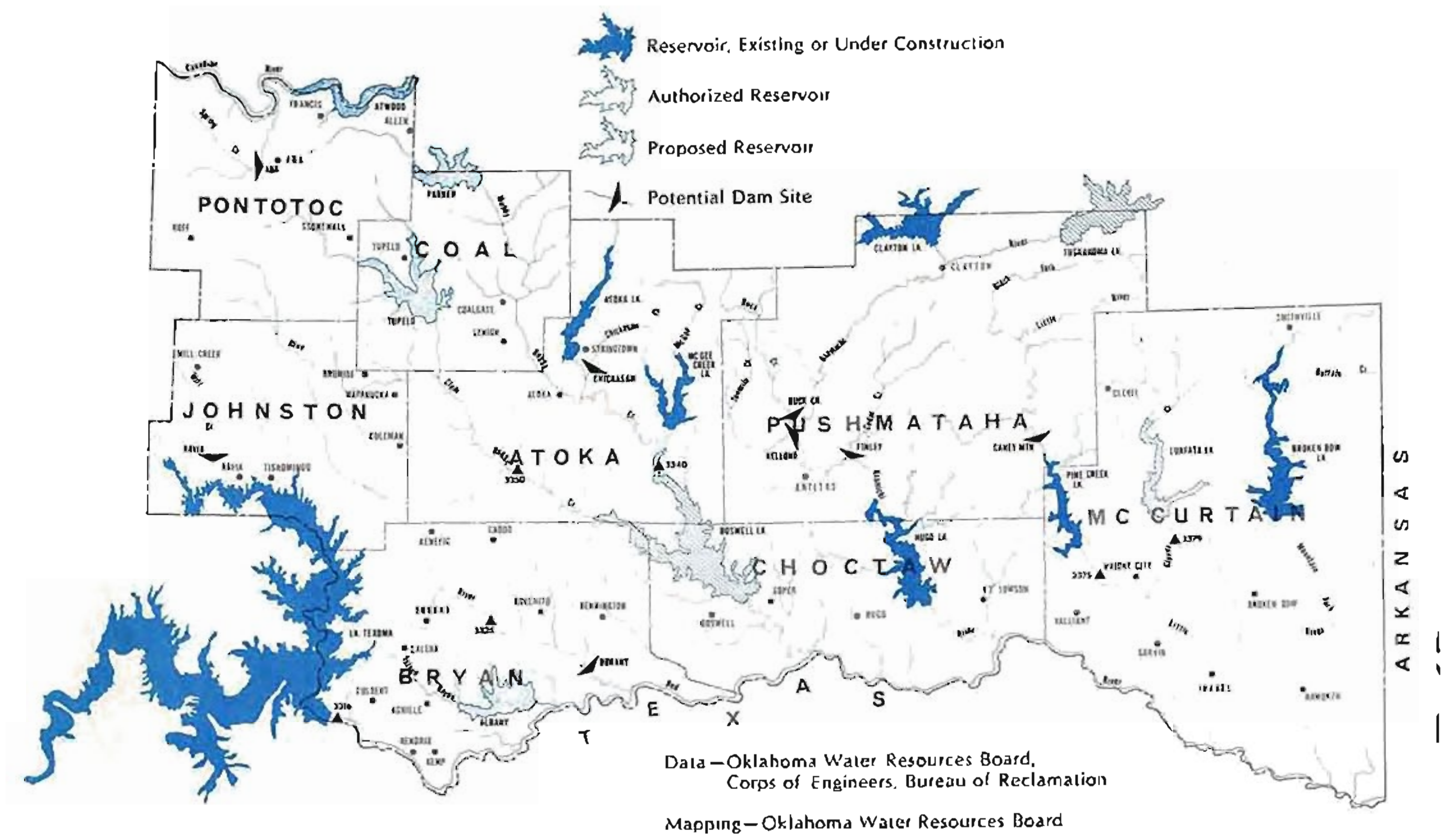
FIGURE 40 SURPLUS WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Total Yield	Local Allocation	Potential Surplus
Atoka	65.0	1.2	63.8
Broken Bow	196.0	47.3	148.7
Hugo (Initial)	165.8	32.8[1]	133.0
Pine Creek	134.4	102.4[2]	32.0
Clayton	156.8	11.2	145.6
McGee Creek	71.8	7.0	64.8
Tuskahoma	224.0	2.2	221.8
Albany	35.8	32.5	3.3
Parker	47.0	15.5	31.5
Tupelo	100.8	67.5	33.3
Ground Water & SCS & Municipal Lakes	981.4	284.0	697.4
Subtotal	2178.8	603.6	1575.5
Other Potential Sources			
Hugo (Stage 2)	91.8	—	91.8
Hugo (Stage 3)	44.8	—	44.8
Boswell	621.4	—	621.4
Lukfata (Ultimate)	212.8	—	212.8
Kellond	56.0	—	56.0
Buck Creek	56.0	—	56.0
Finley	95.2	—	95.2
Caney Mountain	280.0	—	280.0
Durant	134.4	—	134.4
Ada	23.0	—	23.0
Ravia	19.0	—	19.0
Chickasaw	18.0	—	18.0
Broken Bow (Power Releases)	289.0	—	289.0
Subtotal	1941.4	—	1941.4
TOTAL	4120.0	603.6	3516.6

[1] Includes 14,560 acre-feet per year for downstream releases.

[2] Includes 40,320 acre-feet per year for water quality control and 33,600 acre-feet per year presently under contract.

FIGURE 41 PROPOSED PLAN OF DEVELOPMENT



lakes could supply most of the southeastern area's future water needs.

McGee Creek Reservoir, under construction in Atoka County, will not only provide water to the local area, but also supply water to central Oklahoma. Clayton Reservoir, also under construction, and Tuskahoma Lake, authorized for construction in Pushmataha and LeFlore Counties, would serve the region and also be a potential source of supply for areas outside.

Three proposed reservoirs, Albany, Parker and Tupelo, would be needed to supply water to the western part of the region. Albany and Parker would provide municipal and industrial water, while Tupelo would supply water for municipal, industrial and irrigation purposes. Increased ground water development could supply most of the region's irrigation demands, except in Coal County where Tupelo would be located. A total of 282,500 acres are projected to be irrigated requiring 282,500 acre-feet of water per year based on one acre-foot of water per acre.

Municipal and industrial transmission lines to Pushmataha and McCurtain Counties and irrigation distribution facilities from Tupelo Reservoir are included in the proposed Regional Plan of Development.

Figure 42 shows the region's eight counties, their planned sources of supply and projected 2040 wate demands. As indicated, the propose supplies would satisfy projecte demands.

Preliminary cost estimates fo development of the local plan ar shown in Figure 43. Total construc tion cost is estimated at almost $29 million, which includes the cost o storage in existing, authorized an proposed reservoirs, increase ground water development and ap propriate distribution facilities. An nual OMR&E costs are estimated a approximately $4 million, with tota average annual equivalent costs o $15.3 million.

FIGURE 42 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Atoka	Bryan	Choctaw	Coal	Johnston	McCurlain	Pontotoc	Pushmataha	Total
				COUNTY					
Municipal and Industrial Component[1]									
Ground Water & SCS & Municipal Lakes	1.2	1.0	1.0	3.0	5.0	0.8	6.7	—	18.7
Broken Bow	—	—	—	—	—	47.3	—	—	47.3
Hugo	—	—	18.3	—	—	—	—	—	18.3
Pine Creek	—	—	—	—	—	62.0	—	—	62.0
Clayton	—	—	—	—	—	—	—	11.2	11.2
McGee Creek	7.0	—	—	—	—	—	—	—	7.0
Tuskahoma	—	—	—	—	—	—	—	2.2	2.2
Albany	—	32.5	—	—	—	—	—	—	32.5
Parker	—	—	—	15.5	—	—	—	—	15.5
Tupelo	—	—	—	—	—	—	50.3	—	50.3
Local Streams	—	—	—	—	—	1.2	—	—	1.2
M & I Supply	8.2	33.5	19.3	18.5	5.0	111.3	57.0	13.4	266.2
Irrigation Component									
Ground Water	32.8	68.1	42.5	—	33.8	44.6	27.1	16.4	265.3
Tupelo	—	—	—	17.2	—	—	—	—	17.2
Irrigation Supply	32.8	68.1	42.5	17 2	33.8	44.6	27.1	16.4	282.5
TOTAL LOCAL SUPPLY	41.0	101.6	61.8	35.7	38.8	155.9	84.1	29.8	548.7
2040 DEMAND	41.0	101.6	61.8	35.7	38.8	155.9	84.1	29.8	548.7

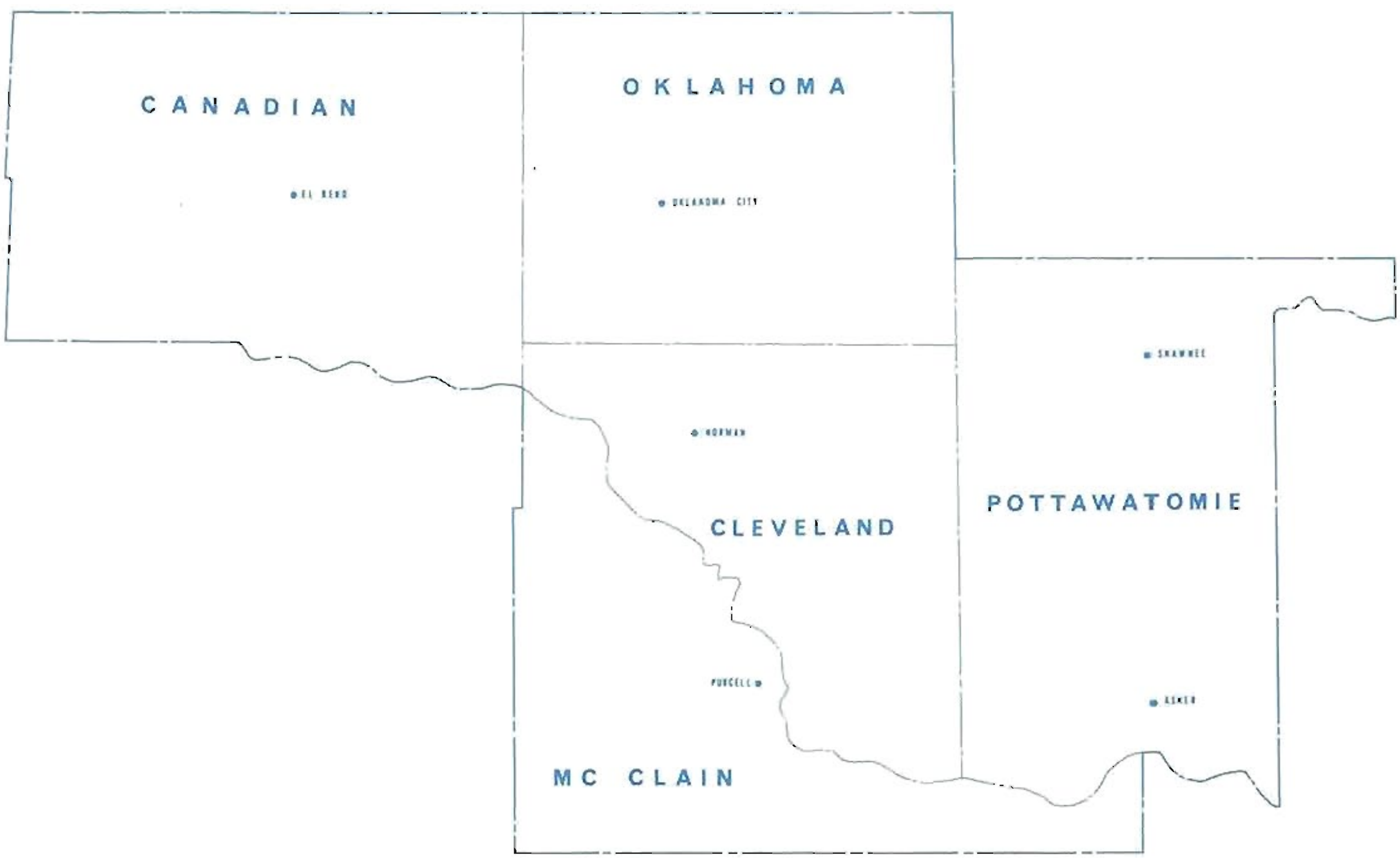
[1]Includes cooling water (power) demands.

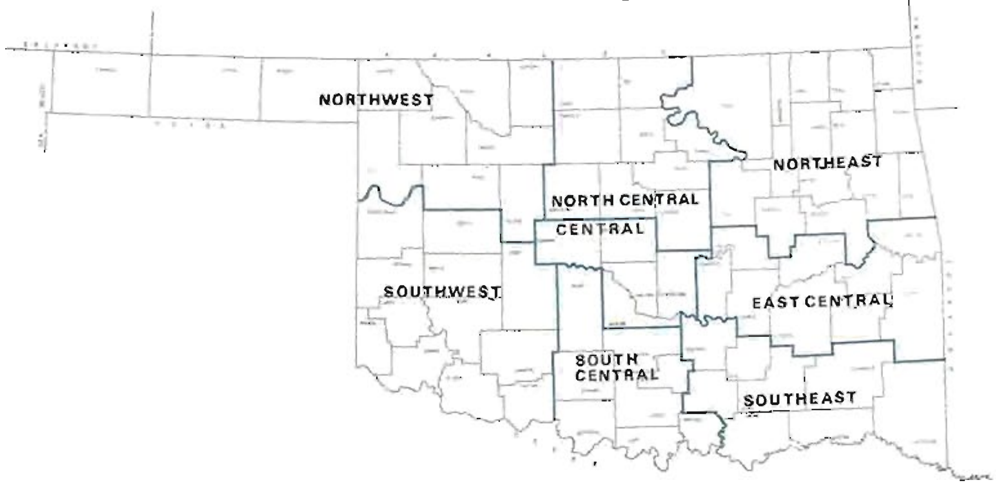
FIGURE 43 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
M & I Water Supply System			
Water Supply Storage[4]	$112,300	$ 510	$ 5,670
Ground Water Development	100	20	25
Water Conveyance Facilities	10,100	375	875
Terminal Storage	9,700	160	710
Subtotal	$132,300	$ 1,065	$ 7,280
Irrigation System (Excluding Wells)			
Water Supply Storage	$12,400	$ 5	$ 80
Terminal Storage	4,000	70	365
Distribution System	37,200	200	1,465
Subtotal	$ 53,600	$ 275	$ 1,910
Irrigation Wells	$103,900	$ 2,670	$ 6,145
Subtotal	$103,900	$ 2,670	$ 6,145
TOTAL	$289,800	$ 4,010	$15,335

[1]Based on January 1978 prices levels and a 100-year period of analysis.
[2]Based on a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Based on 3 1/8 percent interest for Hugo Lake, 3 1/4 percent interest for Clayton and Tuskahoma Reservoirs, and 6 1/8 percent interest for McGee Creek Reservoir. Cost of McGee Creek is based on 28,000 acre-feet per year (39 percent of 71,800 total yield) and reflects allocated cost of total project.

CENTRAL PLANNING REGION





The Central Planning Region consists of Canadian, Cleveland, McClain, Oklahoma and Pottawatomie Counties, an area of 3,544 square miles. The region exhibits a sharp contrast in development, with open farmlands in the west and heavy urban and industrial growth in the center and eastern portions.

The terrain varies from red, sandy prairies in western areas to wide alluvial plains in the east. Elevations range from approximately 1,450 feet above mean sea level in western Canadian County to 1,000 feet in southeastern Pottawatomie County. Most of the region is drained by the North Canadian and (South) Canadian Rivers. Other major streams in the area are the Little River and upper reaches of the Deep Fork.

Population estimates for the year 1977 for the region showed a total of 768,500 in the 5-county area, compared to 699,092 in 1970; the 10 percent increase corresponding with the statewide average.

Between 1970 and 1977 per capita personal income rose from $3,209 to $5,795, while average annual covered employment increased from 167,526 to 264,397, with most of those employed in wholesale and retail trade, personal services and manufacturing.

Even though Oklahoma City's population is not presently growing as fast as in the past, the Oklahoma City metropolitan area's population is increasing rapidly due to the accelerated growth of suburbs such as Edmond, Moore, Yukon and Mustang. This growth has brought with it a greater demand for municipal and industrial water. Continued economic and social growth is anticipated, assuming the metropolitan Oklahoma City area is able to augment its available water supplies.

Industry plays an important role in the economy of this region, fostering associated water and air pollution problems. Measures to combat such environmental problems must be addressed in area planning if prosperity is to continue.

The Central Planning Region has a climate characterized by pronounced and rapid changes in the weather, but only gradual seasonal changes. Thunderstorms producing high rainfall intensities over limited areas frequently occur during the late spring and summer months. Fall and winter storms usually last longer, with lower intensities of precipitation over larger areas.

Prevailing winds across the region are generally southerly, with northerly winds dominant during January and February. Numerous spring and summer tornadoes throughout the area have caused it to be nicknamed "tornado alley."

Figure 9 shows average annual lake evaporation ranging from 65 inches in the northwest to 57 inches in the southeast, a rate greatly exceeding the average annual precipitation. High winds and hot temperatures combine to produce high losses on area lakes, so increased storage capacities are needed to compensate for these losses in order to obtain required yields. Mean annual temperatures are between 60° and 62°F throughout the region, with the highest temperature recorded at 116°F in Shawnee and the lowest -17°F in Oklahoma City. The length of the growing season, which is defined as the period between the average date of the last 32° temperature in the spring and the average date of the first 32° temperature in the fall, is about 210 days.

As shown in Figure 8 , average annual precipitation varies from 28 inches in the northwest to 38 inches in the southeastern portion. May is the wettest month of the year, providing 15 percent of the year's total moisture, and spring is the wettest season, accounting for 33 percent of the annual total. Snowfall in the area averages approximately nine inches annually.

Most flooding in the central region is attributed to intense thunderstorms which cause flood waters to rise rapidly. Flooding frequently occurs in street underpasses and other low-lying metropolitan areas where city storm drains cannot accommodate such concentrations of water. Although these flood waters usually recede within a few hours, low areas along the engorged streams occasionally trap the excess waters for longer periods of time, inflicting severe damage to homes, streets or crops.

In May 1977, six to 8-inch rainfalls in three hours or less caused up to four feet of flooding along Little River at Tecumseh in the southeastern part of the region. Damages were estimated at approximately $2 million in the affected areas.

Serious flood and drainage problems exist along the Deep Fork Basin with major floods occurring on the average of twice each year. The Little River Basin experienced serious flooding problems until 1965, when Lake Thunderbird was completed by the Bureau of Reclamation.

The Corps of Engineers has made channel improvements along the North Canadian on its course through Oklahoma City, which have greatly decreased flooding in the metropolitan area. Smaller Soil Conservation Service watershed projects constructed under the Watershed Protection and Flood Prevention Act have also been effective in controlling flooding.

WATER RESOURCES

Stream Water

Extensive urbanization and industrialization of the Central Planning Region have directed the needs for water primarily to municipal and Industrial uses, although limited irrigation does occur. Quality and quantity problems limit the amount of water available for beneficial uses, so Oklahoma City, the major water user in the area, has developed out-of-basin sources to supplement its supply of suitable water.

Average annual runoff from precipitation in the area ranges from two inches in the northwest to seven inches in the southeast, accounting for approximately 685,000 acre-feet of runoff each year. Discharge varies widely from this runoff as a result of diversions, consumption, regulation by storage and other factors Low flows in the North Canadian and Deep Fork are dependent on Oklahoma City's sewage effluent.

A summary of streamflow records of the four U.S. Geological Survey gaging stations located within the region are presented in Appendix B, Figure 2 .

Inferior water quality in several major streams in this region restricts their use for most beneficial purposes. High mineral and nutrient contents render the natural flows of the (South) Canadian, North Canadian and Deep Fork Rivers only marginal for municipal and industrial use, however with the construction of a reservoir, such as Arcadia on the Deep Fork, the water quality is sufficiently improved for most beneficial uses. Upper Little River is of good quality and can be used for any beneficial purpose. Water quality analysis data for selected U.S.G.S. monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5

The Canadian River in this region is generally of poor quality due to high nutrient and mineral levels. The significant degradation in quality below the Oklahoma City metropolitan area is caused by nutrient contributions from both point and nonpoint sources.

The North Canadian River is very turbid and of generally poor quality due to high nutrient and mineral levels. Oklahoma City's effluent greatly contributes to the North Canadian's poor water quality. However, the marked degree of degradation occurring at Harrah does improve further downstream.

The Upper Little River is a high quality stream with low mineralization, nutrification and turbidity. The water is very soft, and metal toxicity does not appear to be a problem. As development continues at the headwaters of the river, increased nutrification will contribute to an accelerated rate of euthrophication in Lake Thunderbird, which could potentially present a serious problem

The Deep Fork River in the Central Planning Region exhibits fair water quality, with occasional high nutrient levels and moderate mineralization from point and nonpoint sources in the Oklahoma City metropolitan area. The water is hard and slightly alkaline, and becomes increasingly turbid as it flows downstream into Eufaula Lake.

In order to meet the national goals of fishable, swimmable waters by 1983, it is anticipated that Oklahoma City will need to subject its effluent to tertiary treatment. With such treatment, the water in these rivers could potentially be used for municipal and industrial purposes.

STREAM WATER DEVELOPMENT

Industrial contamination from upstream sources and urban runoff have rendered the quality of the water in the region poor for municipal use, so stream water development has been limited to a few reservoirs in which the water quality is suitable for most beneficial uses

There are six major lakes existing in the central area; Draper, Hefner, Overholser, Thunderbird, Shawnee and Arcadia, providing a combined water supply yield of 146,200 acre-feet for municipal and industrial purposes.

Major Reservoirs

Lake Thunderbird, constructed by the Bureau of Reclamation, is the only federal lake in the region. It is located on Little River about eight miles east of Norman in Cleveland County. The quality of water in Thunderbird is excellent, making it suitable for all beneficial purposes. The Central Oklahoma Master Conservancy District has allocated 21,700 acre-feet of water from Thunderbird to supply the municipal and industrial needs of Norman, Midwest City and Del City. The lake is a major recreational area in central Oklahoma.

Modification of Lake Thunderbird to augment the water supply storage is currently under study by the Bureau of Reclamation. Through such modification, additional water could be impounded from out-of-basin sources to provide a greater yield to meet the future water needs of central Oklahoma.

Arcadia Lake was authorized in 1970 for construction by the Corps of Engineers for the purposes of water supply, flood control and recreation. The project is currently under construction on Deep Fork Creek in far northeast Oklahoma County. The full yield, 12,320 acre-feet, has been appropriated to the City of Edmond for municipal and industrial water supply purposes.

Funding was approved by Congress to allow the Corps of Engineers to begin acquiring land for the project in FY 1980. Completion is expected approximately five years following site acquisition.

Major Municipal Lakes

There are four major municipal lakes located in the central area, three supplying the Oklahoma City area and one supplying the City of Shawnee.

Lake Stanley Draper, located on East Elm Creek, was built by the City of Oklahoma City in 1962. Draper Lake is a terminal storage reservoir containing 100,000 acre-feet of water supply storage with an annual yield of 41,000 acre-feet provided by water pumped from Atoka Lake in southeastern Oklahoma. Water quality is excellent for any beneficial use and the lake is used for a variety of recreational activities.

Lake Hefner, built by the City of Oklahoma City on Bluff Creek in far northwest Oklahoma City, is made unique by its 1,155-acre drainage area, which is so small it aids little in its replenishment. Thus, the principal inflow is through diversion of water from the North Canadian River, often originating with releases from Canton Lake upstream flowing by gravity through the Bluff Creek canal to Lake Hefner. Water quality of the lake is fair, allowing its use for most beneficial purposes.

Lake Overholser, constructed by the City of Oklahoma City, is located on the North Canadian River. A channel along the east side of the lake allows poor quality water during periods of low flow to bypass the lake. The yield of Lake Overholser is also supplemented by Canton Lake releases. Because the water quality of the reservoir is fair, it may be used for most beneficial purposes including recreation.

Shawnee Lake, which is actually two separate lakes connected by a 10-foot deep canal near the two dams, was built by the City of Shawnee on South Deer Creek seven miles west of the city. The larger lake was built in 1935 with a storage capacity of 22,600 acre-feet and the smaller one in 1960 with 11,400 acre-feet of storage. Combined yield from the two lakes is 4,400 acre-feet.

Soil Conservation Service Projects

Numerous Soil Conservation Service flood control structures have been planned and constructed in the Central Planning Region. In addition to watershed protection and flood prevention, these lakes are used for municipal and irrigation water supply and recreational purposes. Multipurpose sites in the area provide excellent recreation facilities for the Cities of El Reno and Lindsey, and the City of Maysville utilizes a multipurpose structure for its water supply.

Of the 31 SCS watersheds in the area, 16 are completed or under con-

FIGURE 44 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Arcadia Lake+	Deep Fork Creek	WS, FC, R	70,700	27,380	12,100
Draper Lake	East Elm Creek	WS, R	0	100,000	86,000[1]
Lake Hefner	Bluff Creek	WS, R	0	75,000	17,000[2]
Lake Overholser	North Canadian River	WS, R	0	17,000	5,000[2]
Lake Thunderbird	Little River	WS, FC, R	76,600	105,900	21,700
Shawnee Lakes	South Deer Creek	WS, R	0	34,000	4,400
TOTAL			147,300	359,280	146,200
		POTENTIAL			
				CONSERVATION STORAGE	
West Elm[3]	West Elm Creek	WS, R	0	103,600	0[3]
TOTAL			0	103,600	0
TOTAL YIELD					146,200

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

+ Under Construction

[1]Draper Lake is a terminal storage lake for water pumped from Lake Atoka via Atoka pipeline. McGee Creek Reservoir, currently under construction, will also supply water to Draper Lake. The 86,000 acre-feet per year yield is the capacity of the Atoka pipeline (90 mgd) minus evaporation losses.

[2]Yields do not include releases made from Canton Reservoir.

[3]Proposed terminal storage reservoir and develops no local yield.

struction; four are planned; and 11 have potential for development. See Figure 26.

Authorized Development

There are no other authorized projects in the Central Planning Region.

Potential Development

The potential for additional major stream water development projects in the Central Planning Region is limited by the number of suitable dam sites available, water availability and water quality considerations. The West Elm Creek site has been studied as a potential terminal storage reservoir to hold water conveyed from outside sources and will develop no appreciable yield of its own.

Increasing population and vigorous industrial development may cause the Central Planning Region to face severe water shortages that could retard future economic development. Alternative water supply sources must be made available if healthy development is to continue.

STREAM WATER RIGHTS

As of February 20, 1979 there were 267 vested stream water rights and permits issued by the Oklahoma Water Resources Board for the appropriation of 224,443 acre-feet of water per year from rivers, streams and lakes in the Central Planning Region. Stream water rights and use are shown in Figure 45 .

Ground Water

Two major ground water basins are located in central Oklahoma: the Garber-Wellington Formation and alluvium and terrace deposits. See Figure 28.

Garber-Wellington Formation (Permian) consists of two formations, the Garber Sandstone and the Wellington Formation. The two units were deposited under similar conditions, both containing lenticular beds of sandstone alternating with shale, and are considered a single water-bearing unit.

The total thickness of the combined formations is 800 to 1,000 feet. Water table conditions exist in the outcrop area of the ground water basin and artesian conditions exist where the Garber-Wellington is overlain by the Hennessey Group. Reported yields from wells range from 70 to 475 gallons per minute (gpm), and average 250 gpm. Chemical analyses of water from the basin indicate that hardness is greater in the upper part of the Garber-Wellington than in the lower portion. Overall, water quality is very good and little if any treatment is required to meet federal and state drinking water standards.

Alluvium and terrace deposits (Quaternary) occur in all five counties along the Canadian and North Canadian Rivers and the Deep Fork arm of the North Canadian. The deposits consist of interfingering lentils of clay, sandy clay, sand and gravel laid down by ancient streams. The coarse sand gravel in lower parts yields water to wells freely, while the upper part is usually fine-grained and less permeable silt or clay with corresponding lower yields. Maximum thickness of the deposits is 90 feet, with an average of 50 feet. Well yields range from less than 100 gpm to as much as 600 gpm; averaging 200 gpm. Hardness is the principal water quality problem, with some samples containing concentrations of more than 500 mg/L. Generally, the water is a calcium magnesium bicarbonate type.

GROUND WATER DEVELOPMENT

Development in the ground water basins of the Central Planning Region is extensive, with withdrawals from the Garber-Wellington beginning prior to 1900. At present, this ground water basin is the principal source of water for municipal and industrial purposes for many of the satellite communities of Oklahoma City. Alluvium and terrace deposits of the North Canadian River supply water to the cities of El Reno, Okarche, Geary and Calumet, with numerous industries and irrigation farmers also using these sources.

The Garber-Wellington has been studied by both the U.S. Geological Survey and the Oklahoma Water Resources Board, with the Board concentrating its study on the area between the North Canadian River and the Canadian River, which includes southern Oklahoma County, all of Cleveland County and the western half of Pottawatomie County. Congress has appropriated $1 million for additional studies by the Environmental Protection Agency that are scheduled to begin soon. Additional development of both the Garber-Wellington and alluvium and terrace deposits ground water basins is probable.

FIGURE 45 STREAM WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Canadian	—	—	1	6,400	29	6,331	—	—	1	220	5	7,479	36	20,430
Cleveland	3	2,560	—	—	18	4,797	—	—	1	160	2	218	24	7,735
McClain	2	930	—	—	56	9,340	—	—	1	67	—	—	59	10,337
Oklahoma	2	77,300	3	21,914	43	7,720	—	—	2	741	13	516	63	108,191
Pottawatomie	3	7,405	—	—	79	14,016	—	—	1	15	2	299	85	21,735
Total	10	88,195	4	28,314	225	42,204	—	—	6	1,203	22	8,512	267	168,428

FIGURE 46 GROUND WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Canadian	12	8,883	9	12,460	175	47,655	—	—	9	2,279	3	614	208	71,901
Cleveland	13	43,206	1	36	40	11,357	5	2,694	11	8,684	3	307	73	66,284
McClain	11	1,878	2	424	29	8,225	—	—	2	614	—	—	44	11,141
Oklahoma	48	104,258	24	14,404	50	12,673	—	—	18	4,760	2	46	142	136,141
Pottawatomie	7	2,384	1	1	34	8,527	—	—	5	255	1	4	48	11,171
Total	91	160,609	37	27,325	328	88,447	5	2,694	45	16,592	9	971	515	296,638

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

GROUND WATER RIGHTS

As of July 1979 there were 515 ground water permits issued by the Oklahoma Water Resources Board for the appropriation of 296,638 acre-feet of water per year in the area. See Figure 46. Prior ground water rights have not been determined in this region, however, prior rights hearings are scheduled to begin on the Garber-Wellington aquifer in 1980.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Central Planning Region's 1977 population of 768,500 is projected to rise to 1,550,500 by the year 2040. The current population utilizes an estimated 227,600 acre-feet of water per year for all purposes, with a projected requirement of 819,700 acre-feet annually by 2040. The largest present water usage in the region is for municipal purposes, with industrial use being the next largest. Although municipal and industrial water presently account for over 75 percent of total present water demands, projections indicate an increasingly larger percentage of total water will be used as cooling water for power generation purposes.

Municipal and rural water district water consumption is presently 113,700 acre-feet annually. Due primarily to the anticipated future growth of the Oklahoma City metropolitan area, the Central Planning Region is projected to need 351,600 acre-feet annually for municipal purposes by the year 2040. There are presently 11 rural water systems serving 10,000 customers in the 5-county region, and as the rural areas develop, by 2040 an additional 20,000 people will require service from such districts.

Industries in the region currently use 55,600 acre-feet of water per year. The largest industrial use is in processing and packaging and automobile production. Future water use for industrial purposes is projected to be 272,600 acre-feet annually by 2040, with 54,880 acre-feet of such demand expected to be met by recycled wastewater.

Present utility demand for water is 18,500 acre-feet each year, however, the rapidly escalating demand for electricity in urban centers will cause utility cooling water demands to reach 120,400 acre-feet by 2040. Oklahoma Gas and Electric Company operates three generating plants in this region with a total net capability of 1,558 megawatts.

Most of the water used for irrigation purposes in the Central Planning Region is consumed in Canadian County, which accounts for 16,920 acres of the total 24,640 irrigated acres in the region. The estimated water use for irrigation is 39,800 acre-feet of water per year, primarily supplied from ground water pumped from alluvium and terrace deposits of the Canadian and North Canadian Rivers. Annual irrigation water requirements for a projected 50,000 acres are anticipated to be 75,100 acre-feet by 2040.

FIGURE 47 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	113.7	167.2	191.8	228.0	264.1	324.5	351.6
Industrial	55.6	88.8	119.2	149.5	179.9	226.3	272.6
Power	18.5	39.5	59.6	79.6	99.7	110.1	120.4
Irrigation	39.8	43.3	49.6	56.0	62.4	68.7	75.1
Total	227.6	338.8	420.2	513.1	606.1	729.6	819.7

PROPOSED REGIONAL PLAN OF DEVELOPMENT

The Central Planning Region, the most populous region in the state, is expected to continue its rapid growth of recent years, particularly in Oklahoma City's suburban areas. Many of these suburbs purchase water from Oklahoma City, however, during summer months when water usage is highest, Oklahoma City often is forced to reduce its sale of water in order to meet local demands. Such seasonal demands have often precipitated temporary shortages requiring voluntary or involuntary rationing. Development of additional reservoir sites in the region is virtually precluded by poor water quality induced by natural and man-made pollutants.

Existing sources can supply 208,300 acre-feet per year from ground water, SCS and municipal lakes, and major reservoirs. Potential local development and reuse of waste water could provide an additional 124,400 acre-feet per year, but as shown in Figure 48 , the central region could still experience a deficit of 487,000 acre-feet per year by 2040, which would have to be met from sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development to meet a portion of the region's future water needs. This plan, utilizing resources within the region, includes increased use of ground water, new SCS and municipal lakes and reuse of wastewater effluent. Ground water sources could yield an additional 46,600 acre-feet per year, and SCS and municipal lakes could annually provide 22,800 acre-feet. (See Figure 50 .) Extensive municipal and industrial development in the central region makes available large quantities of wastewater. An estimated 54,900 acre-feet of such effluent per year could be reused for industrial, cooling water (power) and irrigation purposes.

A total of 24,000 acres could be irrigated from the proposed development, based on 1.5 acre-feet of water per acre. Figure 48 shows the five counties in the Central Planning Region, their proposed supplies and 2040 water demands, and indicates that all counties will experience future water shortages of varying degrees.

FIGURE 48 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Canadian	Cleveland	McClain	Oklahoma	Pottawatomie	Total
Municipal and Industrial Component[1]						
Ground Water & SCS & Municipal Lakes	25.4	21.5	19.1	—	17.6	83.6
Overholser & Hefner	—	—	—	22.0	—	22.0
Shawnee Lakes	—	—	—	—	4.4	4.4
Stanley Draper	—	—	—	86.0	—	86.0
Thunderbird	—	21.7	—	—	—	21.7
Arcadia	—	—	—	12.1	—	12.1
Wastewater Reuse	—	4.6	—	23.2	—	27.8
M & I Supply	25.4	47.8	19.1	143.3	22.0	257.6
Irrigation Component						
Ground Water & SCS Lakes	12.6	—	13.4	6.5	15.5	48.0
Wastewater Reuse	20.0	7.1	—	—	—	27.1
Irrigation Supply	32.6	7.1	13.4	6.5	15.5	75.1
TOTAL LOCAL SUPPLY	58.0	54.9	32.5	149.8	37.5	332.7
2040 DEMAND	106.0	145.3	68.6	435.4	64.4	819.7
NET DEFICIT	48.0	90.4	36.1	285.6	26.9	487.0

[1]Includes cooling water (power) demands.

The construction cost of the local proposed development is estimated at $123.4 million, with an average annual equivalent cost of approximately $9.2 million. This cost includes $12.1 million for development of new ground water sources, $6.7 million for new SCS structures, $53.7 million for construction of Arcadia Reservoir in northeastern Oklahoma County, and $51 million for the region's allocated cost of McGee Creek Reservoir in Atoka County. Although Arcadia and McGee Creek are under construction and considered existing supplies, their costs have been included in the local plan in order to more accurately reflect future costs of development. Arcadia, with an average annual equivalent cost of almost $4 million, will serve the Edmond area.

The cost shown for Arcadia includes a gravity flow conduit from the dam to a water treatment facility near the reservoir.

The cost for McGee Creek includes the allocated cost of a pipeline and pumping plant to carry water from McGee Creek to Atoka Lake, where it will connect with the existing pipeline to central Oklahoma for eventual diversion from Lake Stanley Draper. The average annual equivalent cost of the McGee Creek project assigned to the Central Planning Region is estimated at $3.7 million.

FIGURE 49 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[1]	TOTAL AVERAGE ANNUAL EQUIVALENT COSTS
SCS Lakes	$ 6,700	$ 5	$ 355
Ground Water Development	12,100	200	1,200
Major Reservoirs			
Arcadia	53,700	410	3,970
McGee Creek[2]	50,870	320	3,700
TOTAL	$123,370	$935	$9,225

[1]Based on January 1978 prices.
[2]Reflects cost of total project allocated to central region based upon 40,000 acre-feet per year of water (56 percent of 71,800 total yield). Does not indicate the amount of reimbursable cost.

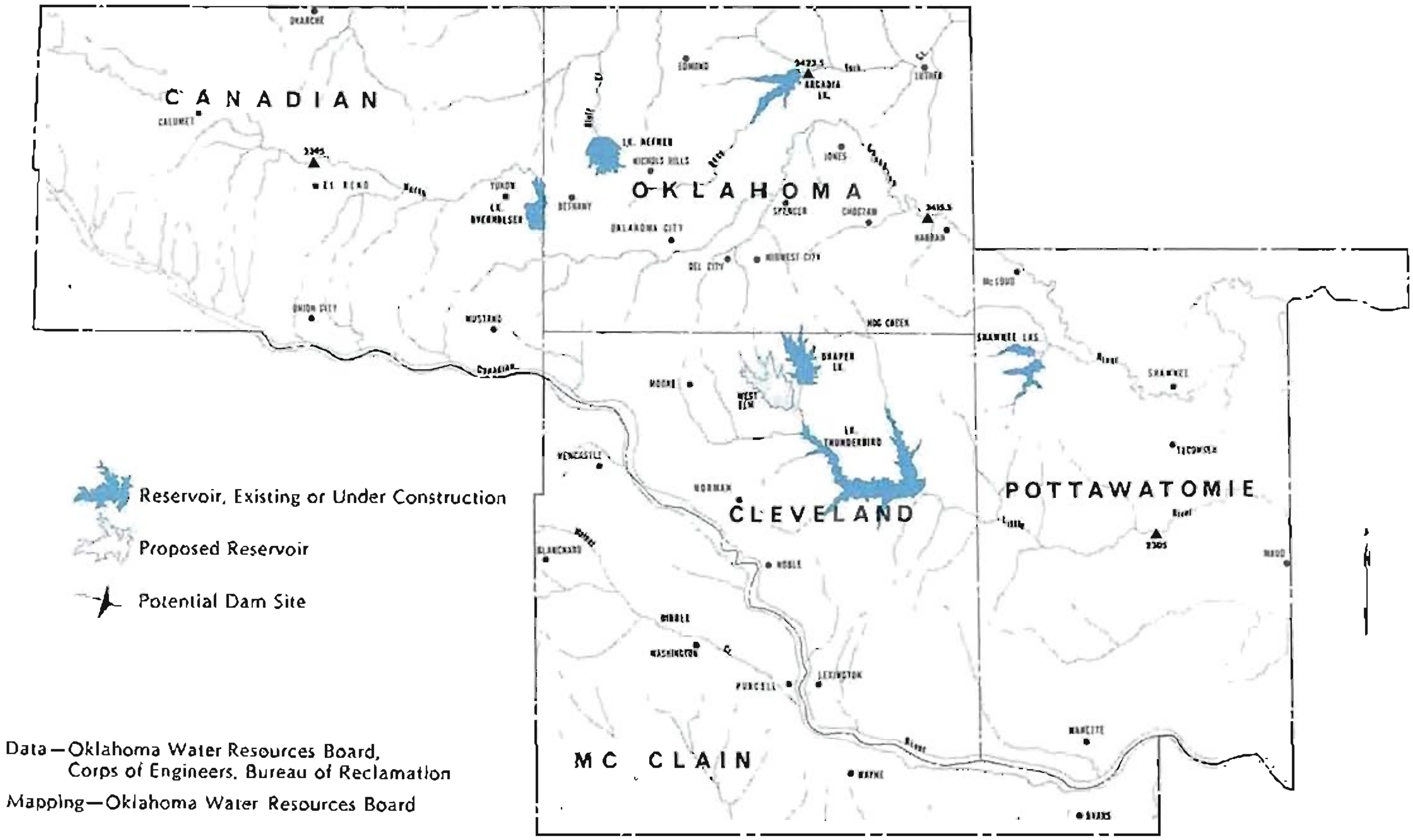


FIGURE 50 PROPOSED PLAN OF DEVELOPMENT

SOUTH CENTRAL PLANNING REGION

also applicable to allocations made on the main stem of the Washita and its tributaries above Pauls Valley, such restrictions specifying that water can be captured or diverted only during periods of high flow or during certain periods of the year. Average annual runoff ranges from three inches in Grady County to seven in Marshall County, as shown in Figure 20 . The average annual runoff originating from the six main stream basins is estimated at 1,500,000 acre-feet per year.

The U.S. Geological Survey maintains 10 continuous streamflow gaging stations on seven of the major creeks and streams in the region. Most of the region's streams eventually enter Lake Texoma, where their combined annual flow for a 49-year period averages 3,400,000 acre-feet.

In parts of the region, water quality is extremely poor, due to excessive amounts of dissolved minerals from natural and man-made sources. Poor quality restricts the use of the water for municipal and industrial purposes and often, even for irrigation. High flows from storm runoff are generally of better quality, thus making these waters available for irrigation if suitable sites can be constructed to capture and store the water. The better quality water required for municipal water use precludes water supply development on some streams. Water quality analysis data for selected U.S. Geological Survey monitoring stations and the station locations are shown in Appendix B, Figure 4 and 5 .

The Red River forms the southern border of this planning region and in this region is highly mineralized, primarily from high concentrations of chlorides from natural sources upstream. Iron and manganese concentrations frequently exceed maximum recommended limits. Limits for chromium, silver, copper and zinc have occasionally been exceeded. Nutrient enrichment on the Red River is highest below Beaver Creek, which has shown recent degradation in water quality and contributes the highest nutrient levels of any tributary to the Red River in the area. This is attributed to extremely high nutrient levels in the Cow Creek tributary to Beaver Creek. Pesticide monitoring in the Red River Basin shows the presence of chlorinated hydrocarbon pesticides and their byproducts in fish tissue and sediment. The high chloride content of the Red River renders this water unsuitable for most beneficial uses, except where some salt-tolerant crops are irrigated from the river using special irrigation management techniques.

The Washita River dominates the northern and eastern portion of this planning region. The lower Washita is highly mineralized due to gypsum outcroppings in its upper drainage basin, and increases in turbidity and hardness as it flows downstream. However, its tributary streams are of sufficient quality to significantly improve the river's overall quality as it flows toward the Red River. The quality of the water ranges from fair to poor with some water quality problems arising from high concentrations of iron, manganese, silver, pH, copper, chromium and mercury.

The Canadian River forms a portion of the region's northern boundary and its water is highly mineralized, exhibits high nutrient levels and often exceeds limits for turbidity and pH. Dissolved oxygen remains at saturation levels. Iron and manganese are present from natural nonpoint sources, and the waters of the Canadian occasionally violate standards for chromium and lead.

STREAM WATER DEVELOPMENT

As shown in Figure 51 , there are lakes (existing and under construction) in this region that provide a total of 2,863,200 acre-feet of flood control storage and 107,700 acre-feet of water supply storage. Of the four major reservoirs in the area, one is maintained by the State of Oklahoma, one by the Bureau of Reclamation and two by the Corps of Engineers. The Soil Conservation Service has four multipurpose sites being utilized as municipal water supplies and recreational facilities. There are also five city lakes and three recreational lakes in the area.

Major Reservoirs

Arbuckle Lake was completed by the Bureau of Reclamation in 1967 for the purposes of water supply, flood control, recreation, and fish and wildlife. The dam is located on Rock Creek, a tributary to the Washita River, in Murray County about six miles southwest of Sulphur.

Water impounded in Arbuckle Lake is of high quality, classified as suitable for all beneficial uses. The Arbuckle Master Conservancy District which provides water to the Cities of Ardmore, Davis, Sulphur, Wynnewood and Dougherty and the Southern Oklahoma Water Cooperative have been allocated the total water supply yield of the reservoir.

Lake Murray, located on a tributary to Hickory Creek in Love County, was completed by the State of Oklahoma in 1937, built primarily as a park lake for recreation. Its surface area is 5,728 acres with a conservation storage capacity of 153,250 acre-feet. Lake Murray is a major recreational attraction in southern Oklahoma. The lake contains no water supply storage.

Lake Texoma (Denison Dam), located on the Red River in Marshall County and the Washita River in Bryan County, is the second largest lake in Oklahoma. The lake, completed by the Corps in 1944, encompasses 143,300 acres of surface area, authorized for the purposes of flood control, water supply, hydroelectric power, regulating flows of the Red River and improving navigation.

The project contains 2,669,000 acre-feet of flood control storage and 1,673,000 acre-feet of power storage. The power plant has two generating units with a capacity of 70,000 kilowatts and the potential for installation of two additional units. Flood damages prevented by the project through December 1978 were estimated at $40,608,000, while power generation averages 244 million kilowatt hours annually.

Texoma has a dependable water supply yield of 23,700 acre-feet per year, however, due to natural salt pollution upstream, the quality of water is poor and the water is not being beneficially used except for emergency supplies. The quality of the water near the dam makes it usable with proper treatment for most beneficial purposes some of the time, while the water quality on the Washita arm is suitable most of the time. Studies by the Corps of Engineers are presently underway to determine the amount of good quality water that can be developed from Lake Texoma. The authorized chloride control project on the Red River would eventually clean up the river's waters and make them usable for most purposes. It should be noted that any future water supply that becomes available must be divided equally between Oklahoma and

FIGURE 51 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
EXISTING OR UNDER CONSTRUCTION					
Arbuckle Lake	Rock Creek	WS, FC, R	36,400	62,600	22,700
Ardmore City Lake	Tributary of Caddo Creek	WS, R	0	2,300	550
Ardmore Mountain Lake	Tributary of Caddo Creek	WS, R	0	4,650	2,800
Ardmore SCS Site 18	Tributary of Caddo Creek	WS, R	1,600	2,600	700
Ardmore SCS Side 13	Tributary of Caddo Creek	WS, FC, R	4,400	4,550	1,950
Clear Creek Lake	Tributary of Wildhorse Creek	WS, R	0	6,000	0[1]
Duncan Lake	Tributary of Wildhorse Creek	WS, R	0	10,000	2,050[1]
Lake Fuqua	Black Bear Creek	WS, FC, R	8,500	17,600	0[1]
Lake Humphreys	Tributary of Wildhorse Creek	WS, R	11,900	10,700	2,750
Lake Murray	Tributary of Hickory Creek	R	0	0	0[2]
Pauls Valley Lake	Washington Creek	WS, R	0	8,500	4,000
Lake Texoma	Red River	WS, FC, P	2,669,000	22,100	11,850[3]
Waurika Lake	Beaver Creek	WS, FC, WQ, R, FW, I	131,900	170,200	16,200[4]
TOTAL			2,863,000	321,800	65,550
POTENTIAL					
				CONSERVATION STORAGE	
Courtney	Mud Creek	WS, R	120,000	261,000	53,000
Gainesville	Red River	WS, P, R, FW, I	0	1,816,600	400,000[5]
Purdy	Rush Creek	WS, FC, R	45,000	140,000	20,000
TOTAL			165,000	2,217,600	473,000
TOTAL YIELD					538,550

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage than can be economically justified as a project purpose.

[1]The combined yield of Clear Creek Lake, Lake Fuqua and Lake Duncan equals 2,050 acre-feet per year.

[2]Lake Murray has a conservation storage of 153,250 acre-feet. The lake has no water supply storage.

[3]Lake Texoma is an interstate lake and all plans for utilization are subject to compact agreements between the States of Oklahoma and Texas. Existing water supply storage will yield 23,700 acre-feet per year. Under the terms of the Red River Compact, Oklahoma has a right to one-half of the water supply yield of the reservoir (11,850 acre-feet per year). A restudy of the project is currently underway to determine the feasibility of providing additional water supply storage. Preliminary studies indicate water supply storage yielding 101,000 acre-feet per year for municipal, industrial and irrigation use and the addition of two hydro-power generation units may be economically justified. Water quality is unsuitable for most beneficial uses.

[4]Waurika Lake will yield 44,800 acre-feet per year. This yield includes irrigation storage to provide 5,040 acre-feet per year. Approximately 40.0% (18,400 acre-feet per year) of the yield is allocated to the South Central Region. The other 60.0% (26,400 acre-feet per year) is allocated to the Southwest Region.

[5]Gainesville Dam site is located on an interstate stream. Plans for utilization are subject to compact agreements between the States of Oklahoma and Texas. Yield shown is amount allocated to Oklahoma based on 80% dependability for irrigation purposes.

Texas under the terms of the Red River Compact.

Recreational facilities at Texoma are among the best in the state, attracting approximately 11,125,000 visitors to the area in 1976.

Waurika Lake on Beaver Creek in Jefferson County is one of the newest lakes in Oklahoma, with impoundment occurring in 1977. Onsite construction by the Corps began in July 1971, and completion of the water conveyance facilities is scheduled for 1980. Waurika was built for the purposes of flood control, irrigation, water supply, water quality, fish and wildlife propagation and recreation.

The Waurika project is unique in that the Corps was authorized to develop conveyance facilities as a part of the project. Local interests will repay all construction costs attributable to the water supply features of the project and operate and maintain the facilities. Water rights have been granted to the Waurika Master Conservancy District, which will furnish water to the Cities of Lawton, Duncan, Waurika, Temple and Comanche.

Major Municipal Lakes

Lake Fuqua is located on Black Bear Creek in Stephens County. Constructed in 1961, it is a water supply reservoir for the City of Duncan, providing 8,500 acre-feet of flood control storage and 17,600 acre-feet of water supply storage.

In addition to Lake Fuqua, the City of Duncan also receives municipal and industrial water supply from Clear Creek Lake, Duncan Lake and Lake Humphreys. The combined yield from these four lakes is 4,800 acre-feet per year.

Ardmore City Lake was constructed in 1903 by the City of Ardmore for the purposes of water supply and recreation. The lake contains 2,300 acre-feet of storage, yielding 550 acre-feet per year. The City also utilizes Ardmore Mountain Lake, constructed in 1922 and 1923, which provides an additional 2,800 acre-feet of water supply annually. Both lakes are located on tributaries to Caddo Creek in Carter County.

Pauls Valley Lake, on Washington Creek in Garvin County, was constructed in 1955 by the City of Pauls Valley for the purposes of water supply and recreation. The lake supplies 4,000 acre-feet per year from 8,500 acre-feet of storage.

Soil Conservation Service Projects

Numerous mutlipurpose SCS sites have been planned or constructed, providing municipal and irrigation water and excellent recreation facilities. The Cities of Ardmore, Chickasha, Duncan, Elmore City, Lindsay, Marlow and Maysville utilize these multipurpose lakes for municipal water supplies and recreation.

The Washita River Watershed, which covers most of the 8-county area, is the only major river drainage area in the state in which all the watersheds are developed or under construction. Of the 46 watersheds in the South Central Planning Region, 36 are complete or under construction, nine are planned and one has potential for development. For locations of these watersheds and multipurpose sites, see Figure 26 .

Authorized Development

There are no other authorized projects in the South Central Planning Region.

Potential Development

Additional sources of stream water supplies for use in the South Central Planning Region are potentially available through the development of two large multipurpose reservoir sites listed in Figure 51 . Although no feasibility-level studies have been conducted, preliminary investigations have indicated potential for their future development.

STREAM WATER RIGHTS

As of February 20, 1979 there had been a total of 555 vested stream water rights and permits issued for the appropriation of 625,843 acre-feet of water per year from rivers, streams and lakes in the region. The tabulation by counties and use is shown in Figure 52 .

Ground Water

Five major ground water basins are located in the South Central Planing Region: the Arbuckle Group, Simpson Group, Oscar Formation, Rush Springs Sandstone, Antlers Sandstone and alluvium and terrace deposits. See Figure 28 . Ground water resources serve the need of most rural homes and smaller towns

FIGURE 52 STREAM WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Carter	7	29,056	1	4,680	34	22,051	—	—	2	12,660	3	500	47	68,947
Garvin	8	14,381	2	4,506	91	21,067	—	—	—	—	2	340	103	40,294
Grady	6	35,124	—	—	182	29,106	—	—	—	—	2	520	109	64,750
Jefferson	7	38,976	—	—	46	14,551	—	—	—	—	1	200	54	53,727
Love	—	—	1	5	19	4,628	—	—	1	3,100	—	—	21	7,733
Marshall	3	2,442	1	1,000	27	10,735	3	790	3	303	3	710	40	15,980
Murray	5	32,800	5	34,621	29	41,361	—	—	1	350	6	33,043	46	142,175
Stephens	4	7,414	4	816	42	106,126	1	75	—	—	3	1,782	54	116,213
Total	40	160,193	14	45,628	470	249,625	4	865	7	16,413	20	37,095	555	509,819

and communities, as well as irrigation farmers in the region.

Arbuckle Group (Cambrian-Ordovician) is limestone and dolomite, 5,000 to 6,000 feet thick. Relatively high permeability results from fractures, joints and solution channels in the limestone. In eastern Murray County, the ground water basin is known to produce large quantities of water. Yields of 200 to 500 gpm are common and deeper tests have produced quantities in excess of 2,500 gpm. Although the water may be hard, total dissolved solids are generally low and the quality is good. Well development is sparse at the present time.

Simpson Group (Ordovician) consists of fine-grained, loosely cemented and friable sandstones. The ground water basin crops out in an area of about 40 square miles in southwestern Murray and northeastern Carter Counties. Wells yield 100 to 200 gpm commonly. Water from sandstones is of poor quality at Sulphur, but elsewhere it is usually potable.

Oscar Formation (Pennsylvanian) consists of interbedded shale, sandstone and limestone conglomerate with lithology varying from place to place. The formation is 300 to 400 feet thick and occurs in western Stephens, southwestern Garvin, southwestern Carter and eastern Jefferson Counties. Depth to water is generally 100 feet below the surface. Well yields range from 60 gpm to as much as 400 gpm, but more commonly 150 to 180 gpm are reported. Ardmore, Healdton, Ringling and Duncan are presently using or have used wells in the Oscar Formation for their municipal supplies. Water quality is considered suitable for most purposes. The ground water basin is of major importance locally, but its potential over a broad area is unknown due to lack of information and sparse well development.

Rush Springs Sandstone (Permian) crops out in southwestern Grady and northern Stephens Counties, where it is approximately 280 feet thick. It is generally composed of fine-grained, even to highly cross-bedded sandstone. Wells in the formation yield 10 to 300 gpm. In a few areas, however, there is sufficient saturated thickness to provide water in quantities adequate for municipal supplies. The Rush Springs Sandstone provides moderate amounts of water to the Cities of Rush Springs and Marlow.

Antlers Sandstone consists of as much as 900 feet of friable sandstone, silt, clay and shale. The ground water basin outcrops over an extensive area in Marshall and Love Counties and a small part of Carter County. Well yields range from 50 gpm to as high as 650 gpm and water quality is good in the outcrop area, but deteriorates downdip. The average saturated thickness of the sand is 250 feet.

Alluvium and terrace deposits (Quaternary) were laid down by streams and rivers and consist of poorly sorted interfingering lentils of clay, sand and gravel. The terrace is topographically higher than the alluvium, but hydrologically they constitute a single unit. The ground water basin provides favorable quantities of water in areas adjacent to the Washita and Red Rivers.

Wells yield a maximum of 400 gpm near Lindsay, 1,000 gpm near Pauls Valley and 200 gpm near Wynnewood and Davis, in areas of maximum saturated thickness and coarsest gravel. Most wells yield smaller supplies of 20 to 100 gpm, owing to fine-grain sediments in the alluvial fill. Overall water quality is good, although water is better in the terrace than in the alluvium. The terrace deposits generally receive less water from the adjacent bedrock and are not affected by influent seepage of river water, which may be mineralized.

GROUND WATER DEVELOPMENT

Development of ground water resources in the South Central Planning Region is limited by low yields, small areal extent of its basins and lack of information concerning water quality, recharge, drawdown, static water level and transmissivity. However, wells in the Oscar Formation provide water supplies to Ardmore, Healdton, Ringling and Duncan; wells in the Rush Springs Sandstone supply Marlow and Rush Springs; and wells in the Simpson Group furnish water to Mill Creek and Bromide.

There is potential for further

FIGURE 53 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Carter	10	5,933	—	—	9	6,307	2	1,657	1	100	—	—	22	13,997
Garvin	7	10,875	14	11,186	67	14,458	3	518	—	—	—	—	91	37,037
Grady	8	8,833	3	850	107	24,230	—	—	—	—	—	—	118	33,913
Jefferson	4	2,465	—	—	22	5,517	—	—	—	—	—	—	26	7,982
Love	4	2,285	2	501	21	11,359	—	—	2	8,776	1	400	30	23,321
Marshall	1	40	—	—	5	2,785	—	—	7	2,204	—	—	13	5,029
Murray	1	8,900	3	7,412	10	6,486	—	—	—	—	—	—	14	22,798
Stephens	4	921	1	1	20	3,908	—	—	2	320	2	164	29	5,314
Total	39	40,252	23	19,950	261	75,050	5	2,175	12	11,400	3	564	343	149,391

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

development in isolated areas of good supply. Where it exists, ground water is generally of suitable quality for most purposes, however, some wells in the Oscar Formation in Carter County are threatened with brine pollution from oil field activities.

GROUND WATER RIGHTS

As of July 1979, there was a total of 343 ground water permits issued in the South Central Planning Region. These permits allocate fresh ground water for municipal, irrigation or industrial purposes. The tabulation of data from the Oklahoma Water Resources Board files is shown in Figure 53 .

PRESENT WATER USE AND FUTURE REQUIREMENTS

The South Central Planning Region currently uses an estimated 98,000 acre-feet annually to meet its total water needs; somewhat less than half of this is used for irrigation, with the remainder divided between municipal and industrial use including 1,000 acre-feet per year for cooling water purposes. Future projections indicate the demand for irrigation water will increase three-fold and municipal use will double by the year 2040. Industrial use is projected to increase only slightly during the entire planning period. Total annual water requirements for the region may reach 228,800 acre-feet by 2040.

The region's population is expected to increase from the 1977 figure of 180,500 to 303,900 by 2040, resulting in municipal water demands (including rural requirements) increasing from the present estimated use of 20,400 acre-feet per year to 37,800 acre-feet per year in 2040. Growing populations in Duncan, Ardmore, Chickasha and Pauls Valley will require most of this increase.

There are 48 rural water districts serving over 30,000 citizens in this region. The formation and expansion of rural systems have accelerated in recent years in response to growing rural water demands and it is anticipated that such growth will continue.

Present industrial water use in the area is 34,000 acre-feet per year, consumed largely by oil refineries and machine manufacturers. Industrial use currently is greater than municipal use, however, projections indicate that demand for industrial water will increase by only 6.6 percent, to 38,700 acre-feet annually, by 2040.

Cooling water requirements for power generation are expected to increase from the present figure of 1,000 acre-feet per year to 4,900 acre-feet per year. Oklahoma Gas and Electric Company currently operates one small plant in the region with a generating capacity of 75 megawatts. If additional plants are constructed in this area, it is assumed that water necessary for cooling purposes will be available from local streams.

Irrigation presently requires 42,600 acre-feet of water each year in the South Central Planning Region. In 1977 the Oklahoma State University Irrigation Survey showed 320 farms in the region irrigating 37,900 acres, with almost a third of these acres lying in Grady County. Projections indicate that by the year 2040, the area may need 147,400 acre-feet of water annually to irrigate 88,500 acres.

FIGURE 54 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	20.4	24.7	27.3	30.8	34.3	36.0	37.8
Industrial	34.0	34.5	35.4	36.5	37.6	38.1	38.7
Power	1.0	1.8	2.9	3.6	4.2	4.5	4.9
Irrigation	42.6	69.5	87.8	107.7	127.5	137.4	147.4
Total	98.0	130.5	153.4	178.6	203.6	216.0	228.8

PROPOSED REGIONAL PLAN OF DEVELOPMENT

The South Central Planning Region has experienced limited water development due to water quality constraints and nominal rainfall levels. Inadequate distribution also plagues much of the region, as many areas are not served by any water system. The lack of available water supplies has hindered potential agriculture and agribusiness activities.

Existing water resources in the area — ground water, SCS lakes and Arbuckle and Waurika Reservoirs — can supply 90,000 acre-feet annually. However, due to depletion and quality problems, ground water supplies are projected to decline in the future, thus requiring a portion of the proposed surface water development as a replacement supply. Use of existing supplies by the year 2040 is projected to be 73,400 acre-feet per year. Potential local sources could provide an additional 119,900 acre-feet per year, but as shown in Figure 55 , even if total proposed local development occurred, by 2040 this region would still face an annual deficit of approximately 35,500 acre-feet which would have to be supplied by sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development which could meet part of the region's future water needs. See Figure 56 . It includes expansion of distribution facilities at the two exiting reservoirs and construction of two major reservoirs with appropriate municipal, industrial and irrigation distribution facilities capable of supplying 52,000 acre-feet of water per year. In addition, new SCS structures are proposed within the region which would supply 67,900 acre-feet per year of water for increased irrigation.

Approximately 58,000 acres could be irrigated from the proposed development by the year 2040, based upon 1.5 acre-feet of water per acre.

FIGURE 55 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Carter	Garvin	Grady	Jefferson	Love	Marshall	Murray	Stephens	Total
					COUNTY				
				Municipal and Industrial Component[1]					
Ground Water & SCS & Municipal Lakes	5.0	4.0	1.7	—	2.0	0.7	2.7	5.0	21.1
Arbuckle	11.0	5.1	—	—	—	—	6.6	—	22.7
Waurika	—	—	—	1.3	—	—	—	12.1	13.4
Courtney	11.3	2.7	—	—	—	1.3	—	—	15.3
M & I Supply	27.3	11.8	1.7	1.3	2.0	2.0	9.3	17.1	72.5
					Irrigation Component				
Ground Water & SCS Lakes	9.1	12.1	19.6	7.4	11.6	2.9	6.1	10.3	79.1
Waurika	—	—	—	5.0	—	—	—	—	5.0
Courtney	—	4.9	—	7.5	4.3	—	—	—	16.7
Purdy	—	20.0	—	—	—	—	—	—	20.0
Irrigation Supply	9.1	37.0	19.6	19.9	15.9	2.9	6.1	10.3	120.8
TOTAL LOCAL SUPPLY	36.4	48.8	21.3	21.2	17.9	4.9	15.4	27.4	193.3
2040 DEMAND	36.4	48.8	56.8	21.1	17.9	4.9	15.4	27.4	228.8
NET DEFICIT	—	—	35.5	—	—	—	—	—	35.5

[1]Includes cooling water (power) demands.

FIGURE 56 PROPOSED PLAN OF DEVELOPMENT

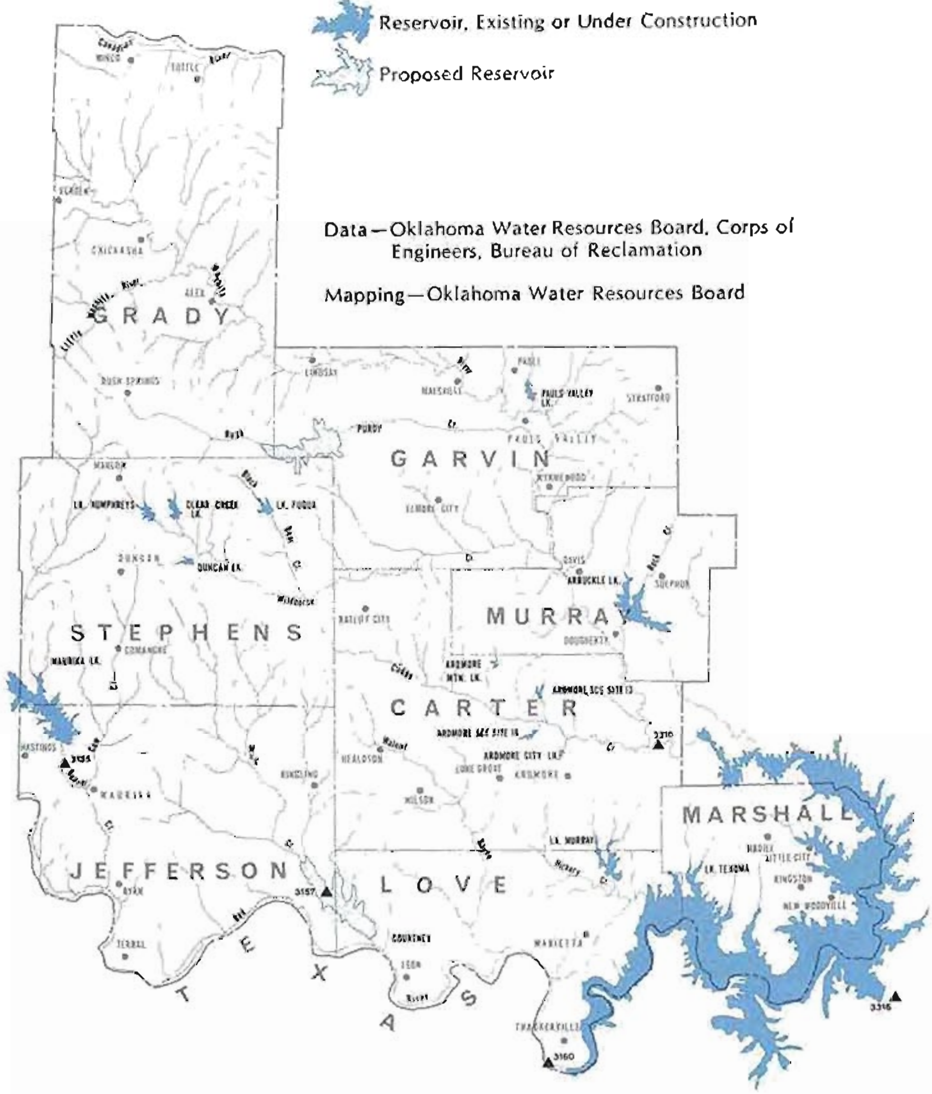


Figure 55 shows the region's eight counties and their proposed sources and projected demands for the year 2040. It should be noted that the regional deficit of 35,500 acre-feet per year is a result of the lack of adequate water sources in the Grady County area.

Figure 57 shows the estimated total cost of development which includes construction costs of $322 million and average annual equivalent cost of $22 million. The cost of water supply storage in new SCS structures is estimated to be $22.6 million, with an average annual equivalent cost of $1.2 million Cost estimates of distribution systems from these SCS structures are not included, but should be addressed in future planning efforts.

The construction cost of major reservoir development and appropriate distribution facilities is estimated at $300 million. This includes construction costs of the proposed Courtney and Purdy Reservoirs, along with appropriate municipal, industrial and irrigation distribution facilities. The cost also includes municipal and industrial distribution facilities from Arbuckle and irrigation distribution facilities from Waurika and appropriate mitigation/compensation costs. The irrigation distribution cost shown is the cost of delivering water to members of the Jefferson County Irrigation District #1. Annual operation, maintenance, replacement and energy (OMR&E) costs are $1.8 million for major reservoirs, with average annual equivalent cost of around $20 million. Additional studies on each of the two proposed reservoirs would be necessary to determine their economic feasibility under federal guidelines, as well as the amount of state or local contributions which would be necessary.

FIGURE 57 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes	$ 22,600	$ 10	$ 1,220
Major Reservoirs			
Arbuckle			
M & I Distribution	23,350	330	2,020
Subtotal	$ 23,350	330	$ 2,020
Waurika			
Irrigation Storage	$ 75	$ —[4]	$ 3[5]
Irrigation Distribution	6,450	60	490
Mitigation/Compensation	590	25	65
Subtotal	$ 7,115	$ 85	$ 558
Courtney			
Dam & Reservoir	$ 48,570	$ 50	$ 3,020
Irrigation Distribution	24,020	310	1,680
M & I Distribution	98,390	680	6,480
Mitigation/Compensation	9,130	25	630
Subtotal	$180,110	$1,065	$11,810
Purdy			
Dam & Reservoir	$ 59,730	$ 40	$ 3,860
Irrigation Distribution	28,660	290	2,010
Mitigation/Compensation	350	25	50
Subtotal	$ 88,740	$ 355	$ 5,920
TOTAL	$321,915	$1,845	$21,528

[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Less than $500 per year.
[5]Interest computed at 3.436 percent.

SOUTHWEST PLANNING REGION

The Southwest Planning Region consists of Beckham, Caddo, Comanche, Cotton, Greer, Custer, Harmon, Jackson, Kiowa, Roger Mills, Tillman and Washita Counties and covers 11,996 square miles. The rich agricultural lands of the region's western plains support more acres of irrigation than any area of similar size in the state. The Wichita Mountains in the east rise 1,000 to 1,100 feet above the general elevation. Major streams are the Red River and its tributaries in the south, the Washita River in the north and Cache Creek near Lawton.

The region's population was estimated at 284,500 in 1977, a six percent increase over 1970 figures. This growth at a rate slightly below the state average is attributed to the steady migration of young adults from rural areas to more attractive industrial employment opportunities in larger cities. Further migration from the region's farms and ranches has been prompted by decreased agricultural production, a result of recent droughts and depressed crop prices

The largest cities in the region are Lawton, Altus, Anadarko, Frederick and Hobart. The distribution of population is 66 percent urban and 34 percent rural.

Average covered employment increased from 27,887 in 1970 to 44,186 in 1977, while per capita personal income rose from $2,859 to $5,470 during the same period. Wholesale and retail trade and service industries exhibited the highest rates of employment, however, these are closely related to agricultural activity in the region. If agricultural production continues its current downtrend, the general economic climate is expected to follow. A change in economic direction can be expected only if additional water can be made available to stimulate agricultural activity.

The region's location near the center of the southern Great Plains is responsible for its warm continental climate of mild winters and long, hot summers. Seasonal weather characteristics are generally well defined and changes between seasons occur gradually, marked only occasionally by rapid change. Spring is the wettest season, with peak rainfall measured over the region in May

The length of the growing season averages approximately 188 days in the northwest and 230 days in the southeastern portion of the region. Strong winds and high temperatures cause the state's highest losses to evaporation, averaging 64 inches annually. See Figure 9 . Mean annual temperature ranges from 59° in the north to 65°F in the south. Annual average precipitation varies from 22 inches in the west to 32 inches in the east, and this variability, along with high evaporation rates, accounts for the region's tendency toward frequent and prolonged droughts, the destructive effect of which have been somewhat mitigated by increased irrigation. The region's annual snowfall accumulation averages 19 inches.

Despite relatively low annual precipitation, severe flooding occurs more than once each year. Flood damages have been significantly reduced through the construction of many flood control watershed projects. The Corps of Engineers regulates flood control storage in the lakes constructed in the region by the Bureau of Reclamation.

Climatic conditions which foster the water problems in this region limit the development of additional major water supply reservoirs and will force dependence on alternative sources as water demands continue to increase.

WATER RESOURCES

Stream Water

All major streams in the Southwest Planning region, except the Washita River, enter the main stem of the Red River, with their combined flow over a 14-year period averaging 555,000 acre-feet per year at the U.S. Geological Survey gaging station at Burkburnett, Texas. Flood control storage in Bureau of Reclamation lakes and Soil Conservation Service flood control structures on the Washita River have significantly decreased damage to property and crops formerly inflicted by the unchecked river.

In contrast, small rainfall amounts and high evaporation rates have caused all major streams in the region to record zero flow at certain times. Two rivers, the Salt Fork and North Fork of the Red, have registered no flow at some time during each year of record. A summary of streamflows recorded at the USGS gaging stations within the region is presented in Appendix B, Figure 2 .

Average annual runoff from precipitation ranges from one inch in the west to 3.5 inches in the southeastern corner, totaling almost 1.3 million acre-feet of water per year See Figure 20.

With few exceptions, the stream water in the Southwest Planning Region is too highly mineralized for municipal or industrial use, and in many cases, unusable even for irrigation. Natural pollutants such as gypsum, chloride and sodium restrict the beneficial uses of available stream water. Water quality analyses data for selected U.S. Geological Survey monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5 .

The Red River marking the southern boundary of the region is a moderately to extremely turbid stream with hard, heavily mineralized water traceable to all the tributaries. High chloride concentrations from salt seeps and springs in the upper part of the river basin in Texas and Oklahoma make the waters of the Red River generally unsuitable for most purposes. Biomagnification and the accumulation of toxic metals and persistent pesticides in the sediment also present problems. Nutrient enrichment is highest below the mouth of Cache Creek, although monitoring in the tributaries shows that marked improvement has occurred in East Cache Creek, primarily due to the City of Lawton's advanced wastewater treatment facilities.

The Elm Fork of the North Fork of the Red River is contaminated by chlorides originating in natural salt seeps and springs near the Texas-Oklahoma border, which make the water unusable for most beneficial purposes. The flows of the North Fork below the mouth of Elm Fork and the Salt Fork of the Red are also unusable due to high chloride concentrations.

FIGURE 58 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Altus Lake	North Fork of Red River	WS, FC, R, I	19,600	146,000[1]	16,800
Clinton Lake	Turkey Creek	WS, R	0	4,400	1,700
Lake Ellsworth	East Cache Creek	WS, R	0	68,700	9,500
Fort Cobb Lake	Cobb Creek	WS, FC, R, I	63,300	78,350[1]	13,300
Foss Lake	Washita River	WS, FC, R, I	180,400	203,700[2]	18,000[2]
Lake Lawtonka	Medicine Creek	WS, R	0	64,000	8,500
Tom Steed Lake	Otter Creek	WS, FC, R	19,500	88,160	16,000
TOTAL			282,800	653,310	83,800
		POTENTIAL			
				CONSERVATION STORAGE	
Altus Lake Modification	North Fork of Red River	WS, FC, R, I	196,000	204,600	8,200[3]
Carnegie Diversion Dam[4]	Washita River	WS	0	0	50,000
Cookietown	Deep Red Run	WS, FC, R, I	78,250	230,200	34,700
Faxon Diversion Dam[5]	West Cache Creek	WS	0	0	10,700
Mangum	Salt Fork of Red River	WS, FC, R	60,000	162,200	15,000
Port	Elk Creek	WS, FC, R	47,700	68,000	14,000
Rainy Mountain	Rainy Mountain Creek	WS, FC, R	66,500	60,000	6,000
Snyder	Deep Red Run Creek	WS, FC, R	11,800	95,000	0
Verden	Spring Creek	WS, R	0	40,000	7,500
Weatherford	Deer Creek	WS, FC, R	44,000	62,500	12,000
TOTAL			504,250	922,500	158,100
TOTAL YIELD					241,900

*WS—Municipal Water Supply, FC—Flood Control, WQ—Water Quality, P—Power, R—Recreation, FW—Fish and Wildlife, I—Irrigation, N—Navigation

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

[1]This includes irrigation storage.

[2]The quality of water from Foss Lake is too mineralized for municipal and industrial use. A 3 MGD (3,360 AF/YR) electrodialysis treatment plant is now in operation. This plant is designed for a maximum output of 4 MGD (4,480 AF/YR). The water supply storage listed above also includes irrigation storage.

[3]Additional yield from modification of Altus Dam.

[4]Diversion dam used in conjunction with Foss Reservoir.

[5]Diversion dam used in conjunction with Cookietown Reservoir.

The Washita River and most of its tributaries contain large concentrations of gypsum, and at times carry dissolved mineral concentrations exceeding 2,000 mg/L. Because area soils will accept the Washita River's high sulfate load, its waters are suitable for irrigation, but do not meet public health drinking water standards on a dependable basis.

The Cache Creek basin exhibits the highest quality water in this region, making water impounded on Cache Creek suitable for most beneficial uses.

Limited quanitites of good quality water severely restrict development of additional water supply storage facilities in this area, so outside sources to fulfill its future water requirements must be considered.

STREAM WATER DEVELOPMENT

The Southwest Planning Region has seven existing reservoirs which provide flood control, municipal water supply, irrigation and recreation for the 12 counties.

Lake Altus, a Bureau of Reclamation project on the North Fork of the Red River, was completed in 1948. The lake contains 146,000 acre-feet of municipal and irrigation water supply storage and 19,600 acre-feet of flood control storage. The major user of lake water is the Altus-Lugert Irrigation District which supplies water to the Bureau's 45,000-acre W.C. Austin Irrigation Project. The City of Altus also obtains part of its water supply from Lake Altus.

Water quality is fair in the North Fork of the Red River above Altus Dam, so the lake's water can be beneficially used for municipal, industrial or irrigation purposes.

Foss Lake, located on the Washita River, was completed by the Bureau of Reclamation in 1961 and authorized for irrigation, flood control, municipal water supply, fish and wildlife, and recreation. The lake contains 180,400 acre-feet of flood control storage, along with 203,700 acre-feet of storage for water supply, including irrigation storage.

Although requiring desalination prior to municipal and industrial uses, with conventional treatment water in Foss is of sufficient quality for irrigation. Many farmers irrigate successfully along the Washita River downstream from Foss. A desalination facility utilizing the electrodialysis process is currently producing one mgd (1,120 acre-feet per year) of water. The plant has an existing capacity of three mgd (3,360 acre-feet per year) and can be modified to produce four mgd (4,480 acre-feet per year). The Foss Reservoir Master Conservancy District supplies the Cities of Clinton, Cordell, Hobart and Bessie with water from Foss.

Fort Cobb Reservoir on Cobb Creek, a tributary of the Washita River, was completed by the Bureau of Reclamation in 1959. The project was authorized for irrigation, flood control, municipal water supply, fish and wildlife propagation, and recreation. The reservoir provides 63,300 acre-feet of flood control storage and 78,350 acre-feet of water supply storages including irrigation storage.

Although the water is high in sulfates, it is rated fair in quality for municipal and industrial purposes and good for irrigation purposes. The reservoir's water supply storage is allocated to the Fort Cobb Master Conservancy District which supplies municipal and industrial water to Western Farmers Electric Cooperative and the Cities of Anadarko and Chickasha.

Major Municipal Lakes

Lake Lawtonka, the original water supply lake constructed by the City of Lawton in 1905, impounds the waters of Medicine Creek. The lake has 64,000 acre-feet of water supply storage, with an annual yield of 8,500 acre-feet.

Quality is excellent, so the water is used for municipal and industrial supplies and recreation.

Lake Ellsworth, completed by the City of Lawton in 1962 to provide additional water supply, is located on East Cache Creek 10 miles north of Lawton. The lake contains 68,700 acre-feet of storage, providing an annual yield of 9,500 acre-feet.

Water quality is excellent, making it suitable for all beneficial purposes. In addition to supplying municipal and industrial water, the lake also provides recreational opportunities.

Soil Conservation Service Projects

The Sandstone Creek watershed project in Roger Mills County is the first completed upland stream detention program in the nation, and is one of numerous projects engineered and constructed by the Soil Conservation Service. There are 54 SCS watersheds in this 12-county region, 41 of them complete or under construction; 13 in planning stages.

In addition to retaining flood waters, these reservoirs are used for irrigation, domestic supplies and recreation. The Cities of Elk City, Sentinel, Cheyenne, Frederick and Clinton utilize Soil Conservation Service multipurpose sites for water supply and recreational purposes. For locations of watersheds and multipurpose structures, see Figure 26 .

Authorized Development

There are no authorized projects in the Southwest Planning Region.

Potential Development

Although there are numerous geographically suitable dam sites available in the Southwest Planning Region, limited water availability and poor water quality limit the potential for additional large stream water development projects. The sites listed in Figure 58 offer the greatest potential for multipurpose development.

STREAM WATER RIGHTS

As of February 20, 1979, a total of 1,227 vested stream water rights and permits had been issued for the appropriation of 634,409 acre-feet of water per year from rivers, streams and lakes in the region. See Figure 59.

Ground Water

Six major ground water basins

FIGURE 59 STREAM WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Beckham	1	2,583	—	—	53	11,542	—	—	—	—	2	20	56	14,145
Caddo	3	30,340	2	3,428	289	32,966	—	—	—	—	3	14,834	297	81,568
Comanche	4	56,600	3	8,442	60	11,462	—	—	1	210	1	13	69	76,727
Cotton	9	3,183	—	—	74	14,598	—	—	—	—	—	—	83	17,781
Custer	9	34,000	—	—	110	13,606	—	—	1	89	7	36,900	127	84,595
Greer	—	—	1	100	15	1,962	—	—	1	4	—	—	17	2,066
Harmon	—	—	—	—	11	1,266	—	—	—	—	1	250	12	1,516
Jackson	2	4,961	1	72	124	108,873	—	—	—	—	—	—	127	113,906
Kiowa	6	59,680	—	—	81	14,440	—	—	—	—	—	—	87	74,120
Roger Mills	2	500	—	—	91	9,244	—	—	—	—	1	50	94	9,794
Tillman	3	7,300	—	—	48	7,981	—	—	—	—	—	—	51	15,281
Washita	3	5,603	1	56	196	29,197	—	—	1	740	1	1,680	202	37,276
TOTAL	42	204,750	8	12,098	1,152	257,137	—	—	4	1,043	16	53,747	1,222	528,775

varying in extent and storage potential exist in the Southwest Planning Region: the Arbuckle Group, Dog Creek Shale and Blaine Gypsum, Rush Springs Sandstone, Ogallala Formation and alluvium and terrace deposits. See Figure 28 . Ground water serves the needs of most rural homes, towns and communities in the southwest region.

Arbuckle Group (Cambrian-Ordovician in age) consists predominantly of carbonate rocks (limestone and dolomite) which outcrop in Comanche, Caddo and Kiowa Counties The ground water basin provides water to wells in the vicinity of Lawton, Cache and Indiahoma. The Arbuckle Group, approximately 6,000 feet in thickness, has high porosity locally, and wells yield 25 to 500 gpm. Where permeabilities are high, water may be suitable for industrial use; however, before it is utilized as a public water supply, quality should be checked for excessive concentrations of fluoride

Dog Creek Shale and Blaine Gypsum (Permian) occur in Harmon and parts of Jackson, Greer and Beckham Counties. The ground water basin consists of interbedded shale, gypsum, anhydrite, dolomite and limestone, characterized in places by solution channels and zones of secondary porosity. Well yields range from less than 10 to as much as 2,000 gpm.

Water levels in the ground water basin respond rapidly to infiltration or precipitation and to the effects of pumping. Due to the erratic nature of solution channels and cavities, it is difficult to predict yields or estimate amounts in storage. Water quality is poor because of hardness and very high calcium sulfate concentrations. In southeastern and northwestern Harmon County, the water has a high sodium chloride content The water, although suitable for irrigation, is not potable.

Rush Springs Sandstone (Permian) outcrops in the Southwest Planning Region in Custer, Washita and Caddo Counties and in a small portion of Comanche County. The aquifer is much more productive in this planning region than in the neighboring South Central Planning Region, where yields are markedly lower and supplies are spotty. It is a fine-grained, cross-bedded sandstone containing irregular silty lenses. Total thickness ranges from less than 200 feet in the south to about 330 feet in the northern part of the region. Depth to water below land surface ranges from zero to 150 feet. Wells yield as much as 1,000 gpm and average about 400 gpm. Most of the water is suitable for domestic, municipal, irrigation and industrial use, however, the water in some portions of Caddo County is very hard with high concentrations of dissolved solids.

The area of heaviest development is in northwestern Caddo County around Sickles, where wells have registered water level declines from 10 to 45 feet over the past 20 years. In adjacent areas, the wells have shown declines of five to 20 feet. In contrast, a few wells in northeast Washita County have risen an average of 31 feet.

The development of ground water from the aquifer has not yet caused critical declines on a widespread basis because of some great localized thickness, but overdevelopment and overpumping in some areas threaten to drop well levels critically low.

Elk City Sandstone (Permian) occurs in western Washita and eastern Beckham Counties. It is similar to the Rush Springs ground water basin in being a fine-grained sandstone with little or no shale; however, it differs in being smaller and considerably thinner. Well yields range from 60 to 200 gpm. Water quality is generally suitable for most purposes.

Ogallala Formation (Tertiary) consists of unconsolidated deposits of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The Ogallala was deposited on an eroded land surface, so its thickness varies greatly. The proportions of the different rock types comprising the Ogallala change significantly from place to place, but sand generally predominates. In the southwest region, the Ogallala occurs in western Roger Mills and Beckham Counties, where it is partly eroded and thins to the east. Yields can be as much as 800 gpm, but because of thinning and erosion, yields are more commonly about 200 gpm. Water quality is good, with low dissolved solids content, and except for hardness, the water is suitable for most uses.

Alluvium and terrace deposits (Quaternary) are interfingering lentils of clay, sandy clay, sand and gravel laid down by streams and rivers. The deposits provide water in the areas adjacent to the Washita River and North Fork of the Red River. The terrace deposits in Tillman County are a source of large quantities of ground water used for municipal, domestic and irrigation purposes.

As a result of increasing irrigation development, ground water supplies are being depleted. Because of the extensive drawdowns in the water table and saline encroachment problems, in November 1968 the Oklahoma Water Resources Board declared Tillman County to be a critical ground water area. In two areas (southwest of Tipton and west of Frederick) overall water levels have declined as much as 19 feet, leaving as little as 12 to 15 feet of saturated thickness. To achieve optimum development, a balance between average annual pumpage and average annual recharge must be established and maintained in the basin.

As required by the Oklahoma Ground Water Act (1972), the maximum annual yield and equal proportionate share of the alluvium and terrace deposits of the North Fork of the Red River in Tillman County have been determined. A computer simulation of all prior appropriative and subsequent allocated pumping rates in relation to the effective date of the Ground Water Act calculates the maximum annual yeild to be 70,000 acre-feet per year. This allows for each landowner overlying the basin to receive an annual proportionate share of the maximum annual yield of 1.0 acre-feet per acre.

GROUND WATER DEVELOPMENT

Present development of ground water is extensive, with overdevelopment occurring in some areas. Well development has increased greatly over the past 10 to 20 years, with ground water supplying domestic, municipal and irrigation needs in the region. Aquifers in the region provide municipal water supplies to Binger, Carnegie, Cement, Fort Cobb, Gracemont, Hinton, Hydro, Lookeba, Weatherford, Clinton, Cordell, Canute, Dill City, Frederick, Tipton, Davidson and Manitou.

Since the area is semiarid and annual rainfall averages only 27 inches, pumpage rates exceed recharge and the ground water is being mined. Well development in the Tillman Terrace deposits has increased from 80 irrigation wells in 1952 to about 570 in 1974, resulting in water level declines up to 20 feet between 1953 and 1972 around Tipton and Frederick. Marked water level declines have also occurred in the Rush Springs Sandstone of Caddo County, where the Sickles area reported declines of 11 to 40 feet between 1956 and 1974. The Dog Creek Shale and Blaine Gypsum may also be overdeveloped, with wells pumping more water than is recharged annually from rainfall. Declining water levels, higher pumping costs, lower well yields and saline water encroachment occur in areas where the aquifers are being overdrafted.

GROUND WATER RIGHTS

As of July 1979, there were 2,895 ground water permits issued in the Southwest Planning Region for the appropriation of 687,180 acre-feet of water. See Figure 60 . Prior rights have been determined on Beckham, Greer, Jackson, Kiowa and Tillman Counties.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Southwest Planning Region

FIGURE 60 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Beckham	11	8,824	1	350	108	28,719	—	—	—	—	—	—	120	37,893
Caddo	21	8,349	10	7,976	888	174,427	1	235	—	—	2	120	922	191,107
Comanche	10	2,085	2	435	41	9,043	—	—	4	1,853	—	—	57	13,416
Cotton	6	3,940	—	—	22	6,004	—	—	—	—	—	—	28	9,944
Custer	8	7,593	1	191	153	33,722	—	—	1	134	—	—	163	41,640
Greer	14	10,305	—	—	151	31,296	—	—	1	403	—	—	166	42,004
Harmon	5	5,204	—	—	362	85,905	—	—	—	—	—	—	367	91,109
Jackson	6	1,225	3	538	222	57,742	1	658	2	321	1	12	235	60,496
Kiowa	9	3,953	1	200	108	18,954	—	—	2	646	1	20	121	23,773
Roger Mills	5	682	—	—	118	26,962	—	—	—	—	—	—	123	27,644
Tillman	20	6,005	—	—	387	83,920	—	—	—	—	—	—	407	89,925
Washita	16	19,071	2	111	167	37,117	—	—	1	1,930	—	—	186	58,229
TOTAL	131	77,236	20	9,801	2,727	593,811	2	893	11	5,287	4	152	2,895	687,180

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

FIGURE 61 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	36.0	45.2	52.0	56.7	61.5	63.9	66.2
Industrial	50.6	55.7	61.7	63.9	66.2	67.3	68.4
Power	5.6	14.8	23.0	28.4	33.7	36.4	39.1
Irrigation	504.4	576.4	631.3	827.4	1023.0	1121.0	1219.1
Total	596.6	692.1	768.0	976.4	1184.4	1288.6	1392.8

is currently estimated to utilize 596,600 acre-feet of water annually to meet the area's total water needs, with irrigation requiring 85 percent of that total. Since total water requirements are expected to continue to increase, the area is projected to require 1,392,800 acre-feet per year by the year 2040.

Population estimates for 1977 show 284,500 residents in the 12-county area, which is expected to increase to 391,800 by the year 2040. Municipal water use should also increase from the estimated 36,000 acre-feet presently used to 66,200 acre-feet annually. The Cities of Lawton and Altus will probably consume most of this increase.

Rural water needs in this area, which are included in the municipal projections, are currently being met by 46 rural water districts which rely almost exclusively on ground water as a water supply source. Future rural water needs are expected to rise significantly and depleting ground water aquifers and deteriorating water quality are expected to force many of these rural water districts to seek alternative water supply sources.

Industrial water use, currently at 50,600 acre-feet per year, is projected to rise to 68,400 acre-feet by the year 2040. The largest industrial water users in the area are a tire manufacturer and various film processing companies.

Current utility requirements in the Southwest Planning Region are estimated to be 5,600 acre-feet annually. Public Service Company of Oklahoma operates two generating plants in the region with a total capacity of over 500 megawatts, and Western Farmers Electric Cooperative operates a plant with a

FIGURE 62 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Beckham	Caddo	Comanche	Cotton	Custer	Greer	Harmon	Jackson	Kiowa	Roger Mills	Tillman	Washita	Total
Municipal and Industrial Component[1]													
Ground Water & SCS & Municipal Lakes	2.8	2.2	1.9	0.3	1.6	2.5	2.0	0.6	—	0.8	2.8	1.8	19.3
Altus	—	—	—	—	—	—	—	—	—	—	—	—	—
Ellsworth	—	—	9.5	—	—	—	—	—	—	—	—	—	9.5
Fort Cobb	—	4.1	—	—	—	—	—	—	—	—	—	—	4.1
Foss	—	—	—	—	1.2	—	—	—	1.0	—	—	1.2	3.4
Lawtonka	—	—	8.5	—	—	—	—	—	—	—	—	—	8.5
Tom Steed	—	—	—	—	—	—	—	8.0	—	—	2.0	—	10.0
Waurika	—	—	23.8	2.6	—	—	—	—	—	—	—	—	26.4
Cookietown	—	—	5.1	—	—	—	—	—	—	—	1.6	—	6.7
Hydro	—	—	—	—	—	—	—	—	—	—	—	—	—
Weatherford	—	—	—	—	12.0	—	—	—	—	—	—	—	12.0
M & I Supply	2.8	6.3	48.8	2.9	14.8	2.5	2.0	8.6	1.0	0.8	6.4	3.0	99.9
Irrigation Component													
Ground Water & SCS Lakes	15.2	97.8	14.0	14.4	12.6	15.6	43.2	28.8	24.8	20.8	40.8	26.6	354.6
Altus	—	—	—	—	—	—	—	25.0	—	—	—	—	25.0
Fort Cobb	—	9.2	—	—	—	—	—	—	—	—	—	—	9.2
Foss	—	—	—	—	7.4	—	—	—	3.8	—	—	3.4	14.6
Tom Steed	—	—	—	—	—	—	—	6.0	—	—	—	—	6.0
Cookietown	—	—	—	15.0	—	—	—	—	—	—	25.4	—	40.4
Hydro	—	44.2	—	—	—	—	—	—	—	—	—	—	44.2
Irrigation Supply	15.2	151.2	14.0	29.4	20.0	15.6	43.2	59.8	28.6	20.8	66.2	30.0	494.0
TOTAL LOCAL SUPPLY	18.0	157.5	62.8	32.3	34.8	18.1	45.2	68.4	29.6	21.6	72.6	33.0	593.9
2040 DEMAND	23.0	209.3	73.4	32.3	45.4	62.5	105.2	297.2	154.8	21.6	297.2	70.9	1,392.8
NET DEFICIT	5.0	51.8	10.6	—	10.6	44.4	60.0	228.8	125.2	—	224.6	37.9	798.9

[1]Includes cooling water (power) demands.

capacity of 374 megawatts. Water needs for power generation are projected to increase to 39,100 acre-feet annually by the year 2040.

Present irrigation water needs are estimated at 504,400 acre-feet of water annually used in the irrigation of 274,531 acres on 2,929 farms producing alfalfa, peanuts, cotton and grain sorghum. Projections for the year 2040 show a potential for 609,550 acres being irrigated, requiring 1,219,100 acre-feet of water annually

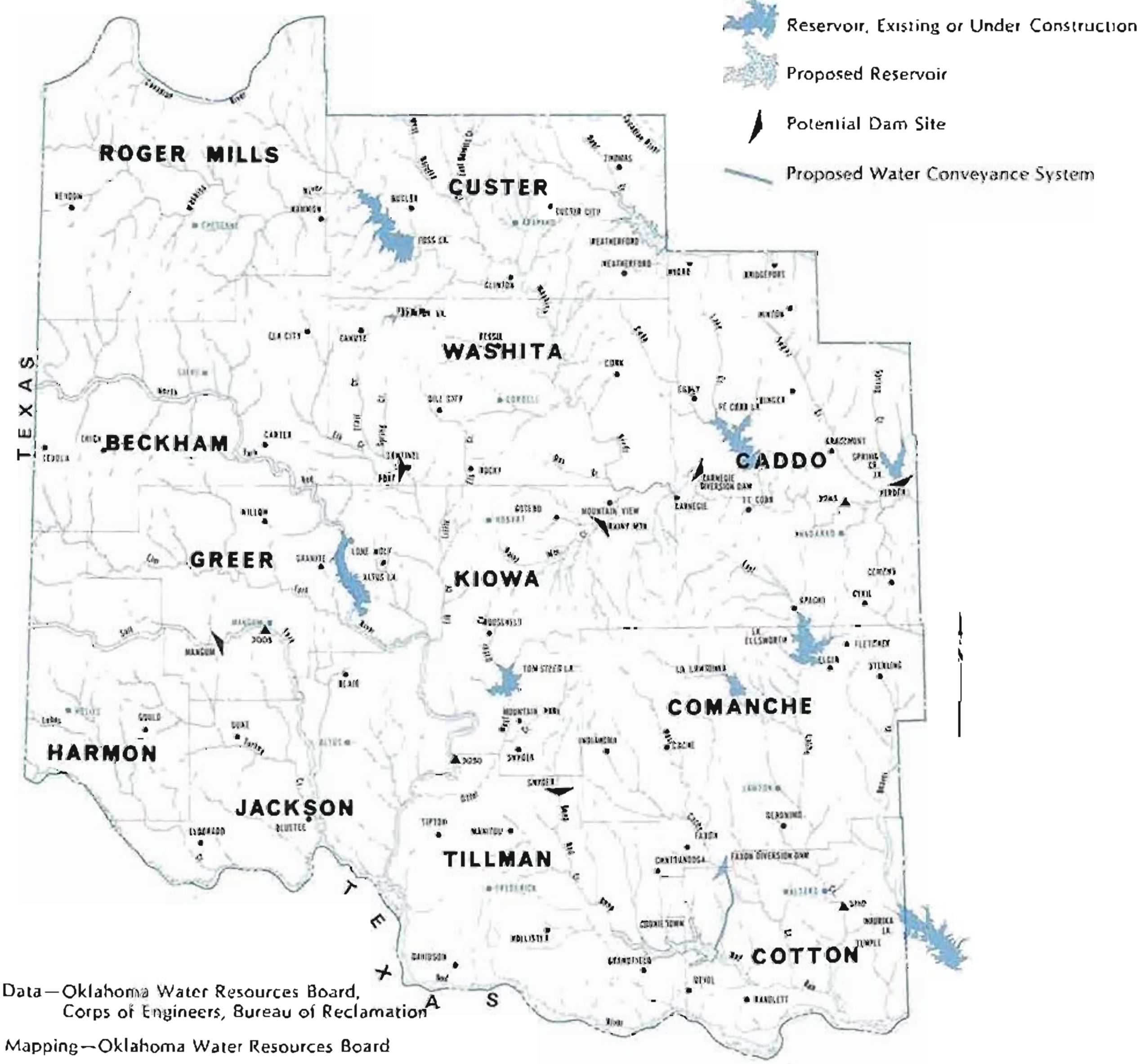
PROPOSED REGIONAL PLAN OF DEVELOPMENT

Chloride and sulfate concentrations in the water of the Southwest Planning Region and inadequate rainfall have limited stream water development and forced reliance on ground water resources. However, depletion and pollution of ground water in this region are placing a strain on future development, making it an unreliable source of a long-term water supply. Inadequate distribution is also a major problem in the region, and many rural areas remain unserved by a water system.

Existing supplies in the region can annually provide 590,000 acre-feet from ground water, SCS and municipal lekes, and major reservoirs. However, declining ground water supplies are expected to limit future use of existing sources to 400,100 acre-feet annually by the year 2040, thus requiring surface water replacement. Potential source sin the area could supply and additional 193,800 acre-feet per year, but the region would still suffer a future deficit of almost 800,000 acre-feet per year which must be supplied from sources outside the region. (See Figure 62 .)

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development to meet a portion of the region's future water needs. (See Figure 63 .) This plan would utilize the local water resources and include the construction of three new reservoirs — Cookietown, Hydro and Weatherford — with municipal, industrial and irrigation distribution

FIGURE 63 PROPOSED PLAN OF DEVELOPMENT



Data—Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation

Mapping—Oklahoma Water Resources Board

facilities. These three reservoirs could provide an additional 103,300 acre-feet per year and planned SCS structures could augment local water supplies with 90,500 acre-feet per year. A total of 247,000 acres would be irrigated by 2040, based on 2.0 acre-feet of water per acre.

Figure 62 shows the 12 counties in the region, their proposed sources and projected 2040 water demands. Even after development of local proposed sources, 10 of the 12 counties would face a deficit.

The estimated total construction cost of local development for the region is approximately $270.2 million, with an average annual equivalent cost of $17.2 million. (See Figure 64 .) New SCS development is estimated to cost $36 million, a cost representing the local cost for water supply storage in an SCS multipurpose project. Costs for distribution facilities from SCS lakes are not included here, but should be addressed in future planning.

The cost of development for the three proposed reservoirs is estimated at $234.2 million, which includes the cost of the three reservoirs, construction of Faxon Diversion Dam, municipal and industrial distribution facilities from Cookietown and Weatherford, irrigation distribution facilities from Cookietown and Hydro and mitigation/compensation costs. Annual OMR&E costs for these facilities are estimated at $1.7 million, with an average annual equivalent cost of $15.9 million. Additional feasibility studies would be necessary to determine each reservoir's economic feasibility under federal criteria, and the portion of state or local cost that could be required.

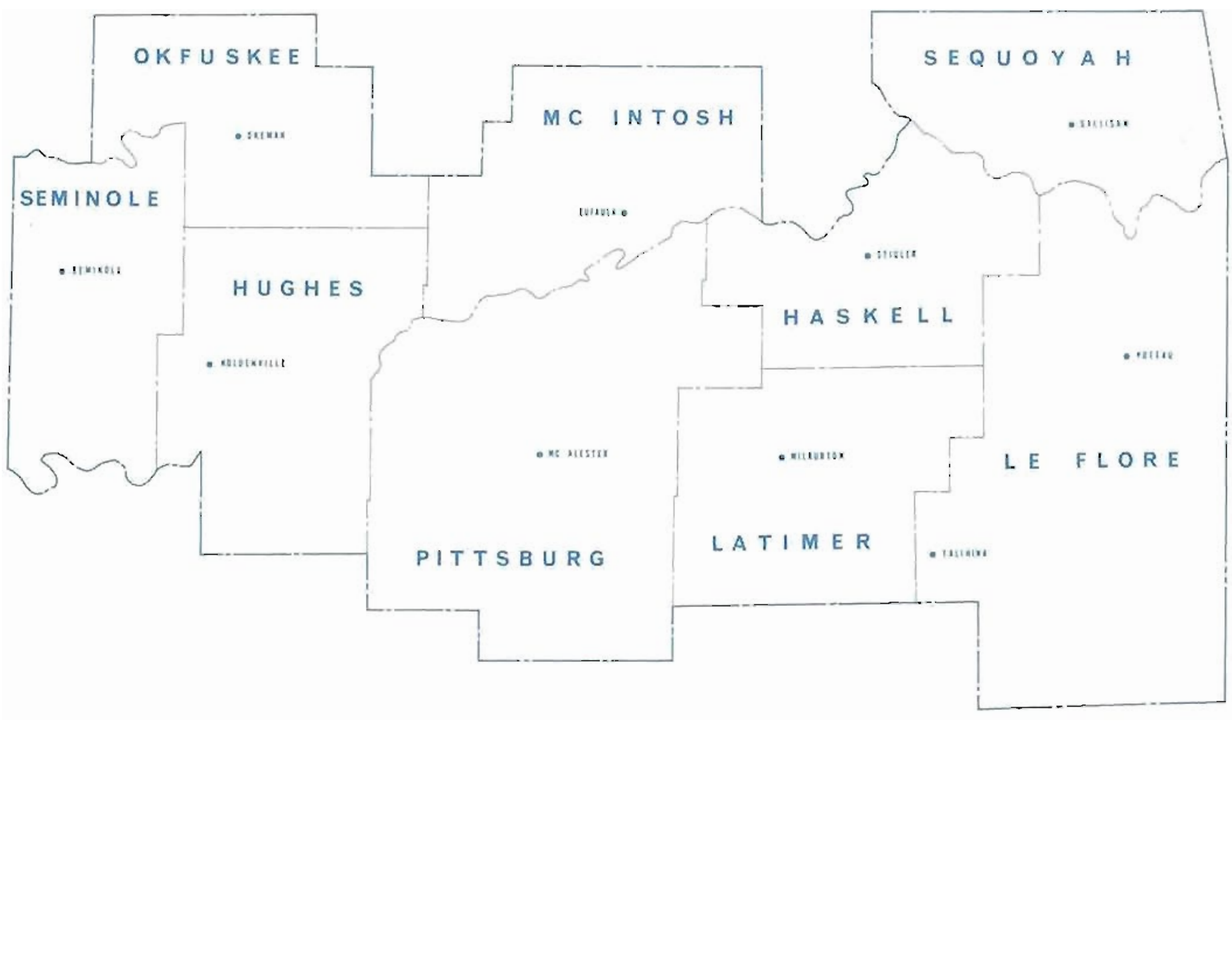
In order to develop a sufficient amount of water from Cookietown Reservoir, a diversion dam would be necessary on West Cache Creek near Faxon in Comanche County. This diversion dam would be connected to Cookietown via a gravity flow canal, allowing a diversion of 47,100 acre-feet per year.

FIGURE 64 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

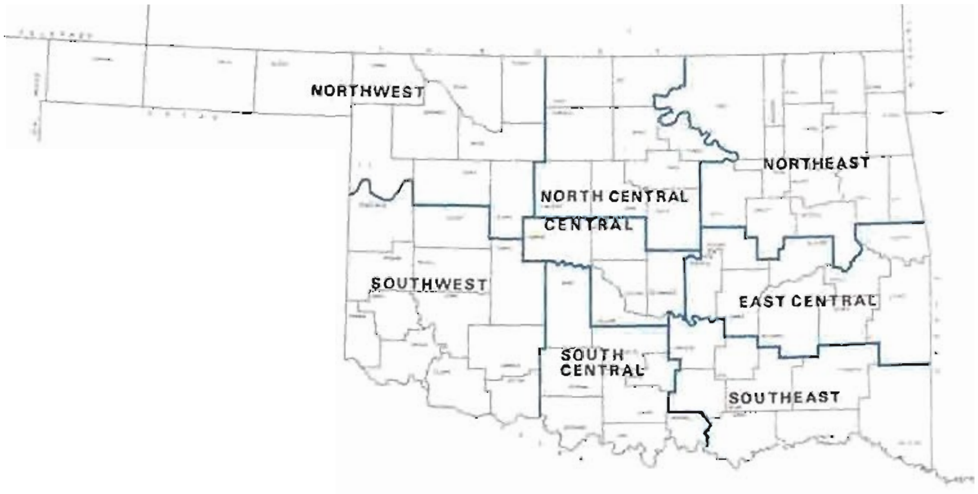
FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes	$ 35,990	$ 20	$ 1,230
Major Reservoirs			
Cookietown			
Dam & Reservoir	$ 62,700	$ 50	$ 4,750
Irrigation Distribution	43,430	570	2,450
M & I Distribution	5,260	90	280
Mitigation/Compensation	11,450	25	780
Subtotal	$122,840	735	$ 8,260
Hydro[4]			
Dam & Reservoir	$ —	$ —	$ —
Irrigation Distribution	47,520	620	3,250
Mitigation/Compensation	—	—	—
Subtotal	$ 47,520	$ 620	$ 3,250
Weatherford			
Dam & Reservoir	$ 33,870	$ 30	$ 2,210
M & I Distribution	11,870	280	690
Mitigation/Compensation	1,540	25	130
Subtotal	$ 47,280	$ 335	$ 3,030
Faxon Diversion Dam[5]	$ 16,500	$ 30	$ 1,345
Subtotal	$ 16,500	$ 30	$ 1,345
TOTAL	$270,130	$1,740	$17,115

[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Dam and reservoir and mitigation/compensation costs for Hydro are included in the costs of local development for the Northwest Planning Region.
[5]Mitigation/compensation have not been determined for Faxon Diversion Dam at this time.

EAST CENTRAL PLANNING REGION



The East Central Planning Region consists of Haskell, Hughes, Latimer, LeFlore, McIntosh, Okfuskee, Pittsburg, Seminole and Sequoyah Counties and covers 7,829 square miles. A portion of the rugged, forest-covered Kiamichi Mountains lies in its southeastern part, the wide alluvial plains of the Arkansas and Canadian Rivers dominate the central portion, and the foothills of the Ozarks cross its northern areas. The elevation ranges from 2,700 feet above mean sea level in the mountainous southeast to 900 feet in the rolling western plains.



Most of the region is drained by the Arkansas, (South) Canadian and North Canadian Rivers. Other streams in the region are the Poteau River, Gaines Creek, lower reaches of the Deep Fork River and the headwaters of the Kiamichi River.

The 1977 population estimate of 190,600 residents for the 12 counties of the East Central Planning Region shows an increase of 10 percent over the 1970 figure of 172,734, which increase is almost identical to the 9.8 percent state average.

Per capita personal income rose from $2,293 in 1970 to $4,258 in 1977, and average annual covered employment rose from 16,983 to 27,024. In spite of this substantial increase in employment, the region's unemployment rate remains very high, registering by far the highest in the state at almost 10 percent during 1974 to 1978. Major industries in the area are wholesale and retail trade, manufacturing and services.

Although the region's vast natural resources present it with a potential for unlimited growth, there has been a net decrease in the number of manufacturing firms conducting business in the region. Development of the region's indigenous resources must be awarded top priority if east central Oklahoma is to experience further social and economic progress.

The region has a warm, moist climate with gradual changes. Spring and autumn months are usually mild with warm days and cool nights, and summers are long and hot. Winters are mild and long periods of cold are uncommon.

Annual lake evaporation is approximately equal to annual precipitation. Evaporation rates vary from 56 inches in the west to 48 inches in the east, very low in comparison to other parts of the state, which is attributable to lower summer temperatures and lesser wind velocities. See Figure 9 . Mean annual temperatures vary from 51° to 62°F across the region, as also shown in Figure 7. These characteristics present the region with conditions ideal for the development of reservoirs and storage facilities, as evidenced by the number of lakes in this area.

The length of the growing season averages 212 days. As shown in Figure 8 , average annual precipitation varies from 37 inches in the northwest to 56 inches in southern LeFlore County, with most rainfall associated with frequent spring thunderstorms. Snowfall in the region averages eight inches annually.

Stream water development in the East Central Region has significantly decreased the extent of flooding and flood damage, however, rapid storm runoff from mountainous drainage areas often causes floods of short duration. Flooding most frequently occurs on the smaller tributaries in the region. The Poteau River and Fourche Maline Creek occasionally share moderate flooding problems. In March 1973 their lower reaches experienced minor secondary crests, and in November and December of the same year high waters damaged roads and bridges. Such activity is typical of flood problems experienced in the spring and fall seasons of most wet years.

The Soil Conservation Service has planned or constructed many watersheds throughout the region, including the Poteau River, Fourche Maline, Sans Bois, Wewoka, Coal, Brushy and Peaceable Creeks.

WATER RESOURCES

Stream Water

Abundant rainfall over the East Central Planning Region provides an adequate quantity of water, but quality factors in some streams restrict their use for certain purposes. Despite these restrictions, a bountiful water supply exists for potential development.

The average annual runoff from precipitation ranges from five inches in the northwest to 20 inches in the southeast corner, generating a total of approximately 4,885,000 acre-feet per year. The mountainous terrain encourages rapid accumulation of rainfall, often producing severe, short-duration flooding. This runoff, plus the flows originating outside the region, constitute a tremendous amount of water flowing through the East Central Planning Region.

A summary of stream flows as recorded at the USGS gaging stations in the region is presented in Appendix B, Figure 2 .

In parts of east central Oklahoma, quality considerations restrict the use of water for beneficial purposes. Waters of the Canadian River above Eufaula Reservoir and the Arkansas River do not meet accepted standards for municipal or domestic use. Natural pollutants and man-made wastes containing organic material and nutrients discharged into these streams degrade water quality. Excessive amounts of dissolved minerals, along with oil brine and sewage effluent, contribute to a high degree of eutrophication of some of the region's reservoir water.

Along with some substandard water, the region possesses an abun-

FIGURE 65 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Eufaula Lake	Canadian River	WS, FC, N, P	1,470,000	56,000	56,000
Robert S. Kerr Lake	Main Stem Arkansas	N, P, R	0	0	0
McAlester Lakes[1]	Coal Creek	WS, FC, R	25,000[1]	24,300[1]	10,500[1]
Tenkiller Lake[2]	Illinois River	WS, FC, P, R	576,700[2]	25,400[2]	17,900[2]
Wister Lake	Poteau River	WS, FC, R, FW	400,000	9,600	6,700
TOTAL			2,471,700	115,300	91,100
		POTENTIAL		CONSERVATION STORAGE	
Atwood	Canadian	WS, R	—	—	44,800[3]
Brazil	Brazil Creek	WS, FC, R	108,000	190,000	87,400
Higgins	Gaines Creek	WS, R	—	195,000	68,400
Peaceable	Peaceable Creek	WS, R	—	—	33,600[3]
Sasakwa	Little River	WS, FC, R	150,000	600,000	135,500
Tenkiller Power and Inactive Storage	Illinois River	WS, FC, R	—	—	392,100[4]
Vian Creek[5]	Vian Creek	WS, R	—	200,000	—[5]
Weleetka	North Canadian River	WS, R	—	—	35,800[3]
Wetumka	Wewoka Creek	WS, FC, R	36,700	70,000	23,900
Wister Lake Modification	Poteau River	WS, FC, R, FW	400,000	835,000[6]	462,600[6]
TOTAL			694,700	2,090,000	1,284,100
TOTAL YIELD					1,375,200

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

[1]The city of McAlester utilizes three lakes for their water supply. The above storages and yields represent the total of the three.

[2]A restudy is currently underway to consider the modification of the existing lake and/or its operation to meet future resource needs of the area.

[3]Storage requirements have not been developed. The yields were based on approximately 60% of the average annual stream flow in the drainage area.

[4]Additional estimated yield that can be developed by converting the hydropower and inactive storage to water supply storage.

[5]Regulating storage reservoir to regulate surplus flows diverted from the Arkansas River.

[6]Additional water supply yield of 462,600 acre-feet per year is based on first, second, and third stage modifications or ultimate development. First stage modification will yield 151,200 acre-feet per year.

dant supply of good quality water which is suitable for most beneficial purposes. Tributary streams of the Arkansas and Canadian Rivers are of good quality, and water in the Poteau River and its tributaries is excellent. Water in Eufaula and Wister Reservoirs is of fair and excellent quality, respectively. Water quality analyses data for selected USGS monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5.

The Arkansas River is the major recipient of the region's runoff from its greater tributaries, the Canadian, Poteau and Illinois Rivers. Waters, via the Arkansas, leave the state on the region's eastern border at Fort Smith, Arkansas. In this region the Arkansas River is a moderately to highly turbid stream with very hard water. The river has relatively low mineralization levels and does not exhibit a toxic metals problem. Nutrient levels are increasing in places, but dissolved oxygen levels remain near saturation most of the time.

The Poteau River drains the southeastern portion of the region with approximately 1,300 of its 1,800 square mile drainage area lying inside the regional boundaries. Levels of nutrients and minerals decrease from the headwaters to Lake Wister, with slight elevations in nutrients observed at stations downstream from the dam.

The Canadian River joins the flow of the Arkansas River in the Robert S. Kerr Reservoir. The segment of the river downstream from Lake Eufaula is of high quality with low enrichment, low mineralization and little evidence of toxic metals. The segment above Lake Eufaula is characterized by elevated phosphorus levels and high solids, primarily chlorides. Lead sometimes exceeds water quality standards in this segment, but no other toxic metals are present in significant concentrations.

The North Canadian River has poor nutrient quality and although less mineralized in this region than in its upstream portions, it is still of poorer quality than other rivers in the area.

STREAM WATER DEVELOPMENT

The East Central Planning Region has experienced extensive development of stream water resources as evidenced by Lake Eufaula and the McClellan-Kerr Navigation System. There are currently four major reservoirs built and maintained by the Corps of Engineers and one group of municipal lakes in the area.

Major Reservoirs

Eufaula Lake, a key unit in the comprehensive development of the Arkansas River Basin, was completed by the Corps in December 1964, authorized for the purposes of flood control, water supply, hydroelectric power and navigation (sediment control). It is the largest lake in the state and the 15th largest man-made lake in the United States, with 143,700 acres of surface area and 600 miles of irregular shoreline. Eufaula is located in McIntosh, Pittsburg, Haskell and Latimer Counties and also extends into Muskogee and Okmulgee Counties in the Northeast Planning Region.

The project supplies 1,470,000 acre-feet of flood control storage and 56,000 acre-feet per year of water supply. The hydroelectric power plant, with three penstocks providing water for three 30,000 kilowatt generating units, has an estimated annual energy output of 317 million kilowatt hours.

Water quality in Eufaula is fair, and is suitable for municipal and industrial use with proper treatment. Natural pollution is contributed by gypsum deposits in the western part of the watershed along with man-made pollution from industrial sources, primarily as a result of past petroleum activities. In recent years, as oil fields upstream from Eufaula have neared depletion, a marked decrease in local chloride concentrations has been noted. It is anticipated that the quality of water in Eufaula will continue to improve.

Current use of Eufaula Reservoir water is limited to numerous small cities and towns, and a substantial amount of water remains available for appropriation.

Robert S. Kerr Reservoir was begun in April 1964 as part of the McClellan-Kerr Navigation System on the Arkansas River, and the lock and dam became operational in December of 1970. The impoundment was authorized for the purposes of navigation, hydroelectric power and recreation. The navigation lock is a single-lift Ohio River type, with culvert and port filling system. The lock chamber is 110 feet wide by 600 feet long and has a maximum lift of 48 feet. The power house is an integral structure with four 27,500 kilowatt units capable of developing a total capacity of 110,000 kilowatts.

The reservoir contains no storage for flood control or water supply, since it is operated as a run-of-the-river project for hydroelectric power generation and navigation.

Tenkiller Lake, located on the Illinois River in Sequoyah County, was completed in July 1953 by the U.S. Army Corps of Engineers. Authorized purposes of the project include flood control and hydroelectric power. The power plant has two 17,000 kilowatt units and is operated remotely from the Fort Gibson power plant. Total flood control storage in the lake is 576,700 acre-feet and the power drawdown is 371,000 acre-feet. There is interim water supply storage of 25,400 acre-feet in the power pool, however, the project is not specifically authorized for that purpose.

The Corps is currently restudying Tenkiller in order to determine the feasibility of adding additional purposes, such as water supply and recreation. Many local towns need water and the excellent quality of water in Tenkiller would make it a viable source. The completion of this restudy is scheduled for 1982.

Wister Lake, located on Poteau River in LeFlore County, was constructed by the U.S. Army Corps of Engineers between 1946 and 1949 for the purposes of flood control and conservation. The lake contains 400,000 acre-feet of flood control storage and 27,100 acre-feet of water

FIGURE 66 STREAM WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Haskell	4	3,133	5	3,822	6	970	—	—	2	75	—	—	17	8,000
Hughes	2	3,593	—	—	111	20,265	—	—	1	743	—	—	114	24,601
Latimer	4	5,165	—	—	15	1,999	—	—	—	—	5	2,764	24	9,928
LeFlore	7	26,725	4	254	54	19,934	—	—	—	—	4	447	69	46,360
McIntosh	7	4,039	—	—	2	298	—	—	9	1,225	—	—	18	5,592
Okfuskee	2	8,724	1	161,280	21	9,470	—	—	—	—	1	56	25	179,530
Pittsburg	9	15,213	2	34,200	21	9,252	—	—	13	398	—	—	45	59,063
Seminole	4	4,244	2	35,000	25	5,464	—	—	—	—	3	340	34	45,048
Sequoyah	14	76,227	4	30,970	32	12,330	—	—	8	5,344	4	5,041	62	129,912
Total	53	147,063	18	265,526	287	79,982	—	—	33	7,815	17	8,648	408	509,034

in the conservation pool, which yields 6,700 acre-feet per year for water supply.

The Corps has considered future modifications of the Wister project, the first of which would yield 151,200 acre-feet per year, with the second stage or ultimate modification providing over 473,000 acre-feet of water supply each year.

The existing water supply is currently being utilized by the Cities of Heavener and Poteau and the Poteau Valley Improvement Authority.

Major Municipal Lakes

Lake McAlester is located on Bull Creek about five miles northwest of McAlester in Pittsburg County. The lake was constructed in 1923 and serves as the water supply for McAlester, providing 11,470 acre-feet of storage.

McAlester has two other city lakes, Talawanda Number One and Number Two, which also provide water supply to the area. The combined water supply yield from all three lakes is 10,500 acre-feet per year.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered construction of numerous flood control structures in the East Central Planning Region for the purpose of watershed protection and flood prevention. Of the 36 SCS watersheds in this region, 13 are complete or under construction, 12 are planned and 11 have potential for development.

In recent years increased emphasis has been placed on multiple uses of these flood retarding structures. In addition to widespread recreation use, many local sponsors have added water storage for municipal purposes. These structures provide water supply to the Cities of Wilburton, Sallisaw and Talihina. See Figure 26 .

Authorized Development

There are no other authorized projects in the East Central Planning Region.

Potential Development

The subhumid climate, along with the large drainage area of the streams in the region, contribute such a large volume of water that it is virtually impossible to provide adequate storage to develop the full potential of the streams. The sites listed in Figure 65 offer attractive potential for multipurpose development.

STREAM WATER RIGHTS

As of Feburary 20, 1979 there are 408 vested stream water rights and permits issued for the appropriation of 459,034 acre-feet of water per year from rivers, streams and lakes in the region. See Figure 66 .

Ground Water

Ground water is available in the East Central Planning Region from two major ground water basins, the Vamoosa Formation and alluvium deposits. Wells in these basins provide water for domestic, municipal, industrial and irrigation purposes. See Figure 28 .

Vamoosa (Pennsylvanian) underlies an area of approximately 600 square miles, including all or parts of the Barnsdall, Hilltop, Tallant, and Vamoosa Formations and the Ada and Vanoss Groups. It is a complex sequence of fine- to very fine-grained sandstone, siltstone, shale and conglomerate interbedded with very thin limestone. Cumulative thicknesses of water-bearing sandstones are greatest south of the Cimarron River, where they reach a maximum of 550 feet in the vicinity of Seminole. North of the Cimarron River, the average cumulative thicknesses of the sandstones are about 100 feet, but locally may be as great as 200 feet.

The quality of water in the Vamoosa is generally suitable for municipal, domestic and stock use. The water in most of the area is of the sodium bicarbonate type, but water from wells which penetrate to near the base of potable water is commonly of the sodium chloride type. Laboratory and field data indicate that both surface and ground water

FIGURE 67 GROUND WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Haskell	1	242	—	—	1	640	—	—	—	—	—	—	2	882
Hughes	3	5,930	—	—	23	8,102	1	360	—	—	—	—	27	14,392
Latimer	—	—	—	—	1	134	—	—	—	—	—	—	1	134
LeFlore	1	31	—	—	7	1,420	—	—	1	160	—	—	9	1,611
McIntosh	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Okfuskee	1	1,000	—	—	5	2,260	1	7,043	2	1,833	—	—	9	12,136
Pittsburg	—	—	—	—	5	967	—	—	—	—	—	—	5	967
Seminole	7	7,072	2	1,525	10	2,812	1	990	4	41	—	—	24	12,440
Sequoyah	—	—	—	—	18	7,492	—	—	1	80	—	—	19	7,572
Total	13	14,275	2	1,525	70	23,827	3	8,393	8	2,114		0	96	50,134

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

have been degraded locally by sodium chloride brines.

Alluvium deposits (Quaternary) occur along the Arkansas and Canadian Rivers and are composed of silts, clay, sand and gravel. The total thickness averages 42 feet, and the average saturated thickness is approximately 25 feet. Reported well yields range from 200 to 1,000 gpm. Yields of at least 200 gpm can be obtained in most areas. Although the water is predominantly of a calcium, magnesium bicarbonate type, variable in dissolved solids content and hard, it is suitable for irrigation, domestic, stock and some industrial purposes.

GROUND WATER DEVELOPMENT

Due the the availability of stream water, ground water development in the East Central Planning Region has been limited. Development of the alluvium deposits is limited to those of the Arkansas and Canadian Rivers. Most of the existing development in the Vamoosa occurs in Seminole and Okfuskee Counties. The cities of Konawa, Maud, Seminole, Boley and Paden, as well as a rural water district near Bowlegs, utilize water from the Vamoosa.

Detailed and accurate ground water information is meager, and considerable work is needed to assess the potential development of the region's ground water basins.

GROUND WATER RIGHTS

As of July 1979, there were 96 ground water permits issued for the appropriation of 50,134 acre-feet of water annually within the region. See Figure 67 . Prior rights have not as yet been determined in any county in the region.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The East Central Planning Region is presently using an estimated 73,400 acre-feet of water annually to meet the area's total water demands. Municipal and power uses consume the greatest amount of water, with irrigation the next largest use. Projections indicate that by the year 2040 the region will require 365,100 acre-feet per year to fulfill its water needs, with a dramatic increase in water for cooling purposes expected.

The population of the east Central Region is expected to increase from 190,600 in 1977 to 280,300 by the year 2040, an increase resulting in municipal and rural water needs rising from the present 33,800 acre-feet per year to 70,800 acre-feet annually by 2040. The majority of this increase will be due to the expected growth of the Cities of McAlester, Poteau and Seminole.

Rural water needs in the region are currently being met by 60 rural water districts supplying water to almost 60,000 people. Future needs will be met by expanded rural water systems and water districts.

Industrial water use in the region is currently 9,300 acre-feet per year, with the largest users being clothing manufacturers and oil and gas refineries. Future projections for industrial water needs indicate the region will require 16,900 acre-feet annually by the year 2040.

Use of cooling water for power generation in the area is now 20,800 acre-feet annually. Oklahoma Gas

FIGURE 68 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	33.8	42.0	47.9	54.7	58.7	66.1	70.8
Industrial	9.3	10.9	11.5	12.3	12.9	13.3	16.9
Power	20.8	66.7	103.7	140.7	177.7	204.2	230.8
Irrigation	9.5	29.3	32.7	36.0	39.4	42.9	46.6
Total	73.4	148.9	195.8	243.7	288.7	326.5	365.1

and Electric Company's largest generating plant, with a capacity of 1,562 megawatts, is located in this planning region. Projections indicate a substantial increase in the demand for cooling water in the future, rising to 230,800 acre-feet annually, a sevenfold increase, by 2040.

The Oklahoma State University 1977 Irrigation Survey indicated that the 9-county region contained 25,465 irrigated acres on 172 farms. It is estimated that 9,500 acre-feet of water is presently used for irrigation, with almost half of the total irrigated acreage being located in Hughes County. Projections indicate 47,600 acres will be irrigated by 2040 requiring 46,600 acre-feet of water annually.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Abundant rainfall and runoff ideally suit the East Central Planning Region to further water resource development. Although a few of the region's major streams have been developed, many potential sources remain. Many local residents are served by inadequate distribution facilities which often are tapped into poor quality sources. To meet future water requirements, east central Oklahoma must rely on new sources and the expanded use of existing supplies.

Existing sources within the region can supply 70,400 acre-feet per year from ground water, SCS and municipal lakes, and federal reservoirs. Potential sources could provide enough water to meet the region's 2040 projected need of 365,000 acre-feet per year, with an annual excess over 880,000 acre-feet. (See Figure 72.) The addition of other potential sources not included in the regional plan could increase the annual surplus to approximately 1.4 million acre-feet.

As part of the Oklahoma Comprehensive Water Plan, a Regional Plan of Development is proposed to meet the 2040 water needs of the East Central region. This plan utilized sources within the region and proposes construction of several major reservoirs, increased ground water development, increased usage of existing supplies and construction of appropriate municipal, industrial and irrigation distribution facilities. (See Figure 70.)

Four new reservoirs — Atwood, Sasakwa, Weleetka and Wetumka — would be constructed in the region. The existing Wister Lake would be modified to increase its dependable yield, present use from Eufaula would be increased and use from Tenkiller Lake would be increased, contingent upon reallocation of hydropower

FIGURE 69 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Haskell	Hughes	Latimer	LeFlore	McIntosh	Okfuskee	Pittsburg	Seminole	Sequoyah	Total
				Municipal and Industrial Component[1]						
Ground Water & SCS & Municipal Lakes[2]	1.2	4.4	1.1	4.1	0.7	2.7	12.0	13.7	4.3	44.2
Eufaula	—	—	—	—	4.6	—	5.3	—	—	9.9
Tenkiller	—	—	—	—	—	—	—	—	22.6	22.6
Tuskahoma	—	—	—	0.7	—	—	—	—	—	0.7
Atwood	—	—	—	—	—	—	—	44.8	—	44.8
Sasakwa	—	—	—	—	—	—	—	134.6	—	134.6
Weleetka	—	—	—	—	—	7.8	—	28.0	—	35.8
Welty	—	—	—	—	—	3.2	—	—	—	3.2
Wetumka	—	0.9	—	—	—	0.8	—	14.2	—	15.9
Wister (Modification)	3.8	—	5.5	9.7	—	—	—	—	—	19.0
M & I Supply	5.0	5.3	6.6	14.5	5.3	14.5	17.3	235.3	26.9	330.7
					Irrigation Component					
Ground Water & SCS Lakes	1.5	6.8	2.8	6.4	1.1	2.9	6.3	2.6	5.2	35.6
Eufaula	0.9	—	—	—	—	—	—	—	—	0.9
Tenkiller	—	—	—	—	—	—	—	—	3.8	3.8
Sasakwa	—	—	—	—	—	—	—	0.9	—	0.9
Welty	—	—	—	—	—	1.2	—	—	—	1.2
Wetumka	—	5.2	—	—	—	—	—	—	—	5.2
Irrigation Supply	2.4	12.0	2.8	6.4	1.1	4.1	6.3	3.5	9.0	47.6
TOTAL LOCAL SUPPLY	7.4	17.3	9.4	20.9	6.4	18.6	23.6	238.8	35.9	378.3
2040 DEMAND	5.8	17.2	8.7	21.6[3]	6.2	18.7	21.5	238.8	26.6	365.1

[1]Includes cooling water (power) demands.

[2]Includes present municipal use from federal reservoirs.

[3]Remaining supply (700 acre-feet per year) provided by adjacent county.

storage to water supply storage. Tenkiller is presenty authorized to provide 17,920 acre-feet per year, and reallocation by Congress would be required to supply additional water for municipal, industrial and irrigation purposes. New ground water development could provide an additional 11,000 acre-feet per year to the region. A small portion of the region's supply would be provided by two reservoirs outside the region, yet close enough to serve demand centers more economically than sources within the region. These are the authorized Tuskahoma Reservoir in the Southeast Planning Region and the proposed Welty Reservoir in the Northeast region. Total supply from all existing, authorized and proposed sources would be 1.4 million acre-feet per year. A total of 47,600 acres are projected to be irrigated, based on one acre-foot of water per acre.

Figure 69 shows the region's nine counties, their proposed sources and projected 2040 water requirements. Total supply would slightly exceed demand due to sources in this region serving adjacent counties in a neighboring planning region. LeFlore County would receive a small portion of its total supply from an adjacent county within the region.

As shown in Figure 71 , the total construction cost of all proposed development is estimated to be over $240 million, with an average annual equivalent cost of $18.5 million.

The construction cost of the municipal and industrial water supply system is estimated at slightly more than $200 million, including $149 million for storage, $1.5 million for limited ground water development and $56 million for water conveyance facilities. The annual OMR&E costs for this system are approximately $4.4 million, with an average annual equivalent cost of approximately $16 million.

The irrigation system construction cost is estimated at $37.7 million, including $11.9 million for irrigation storage in potential SCS lakes and existing and proposed major reservoirs, and $25.8 million for distribution facilities from the reservoirs. The annual OMR&E and average annual equivalent costs are $222,000 and $2.8 million, respectively. Distribution costs from SCS lakes are not included, but should be addressed in future planning.

FIGURE 70 PROPOSED PLAN OF DEVELOPMENT

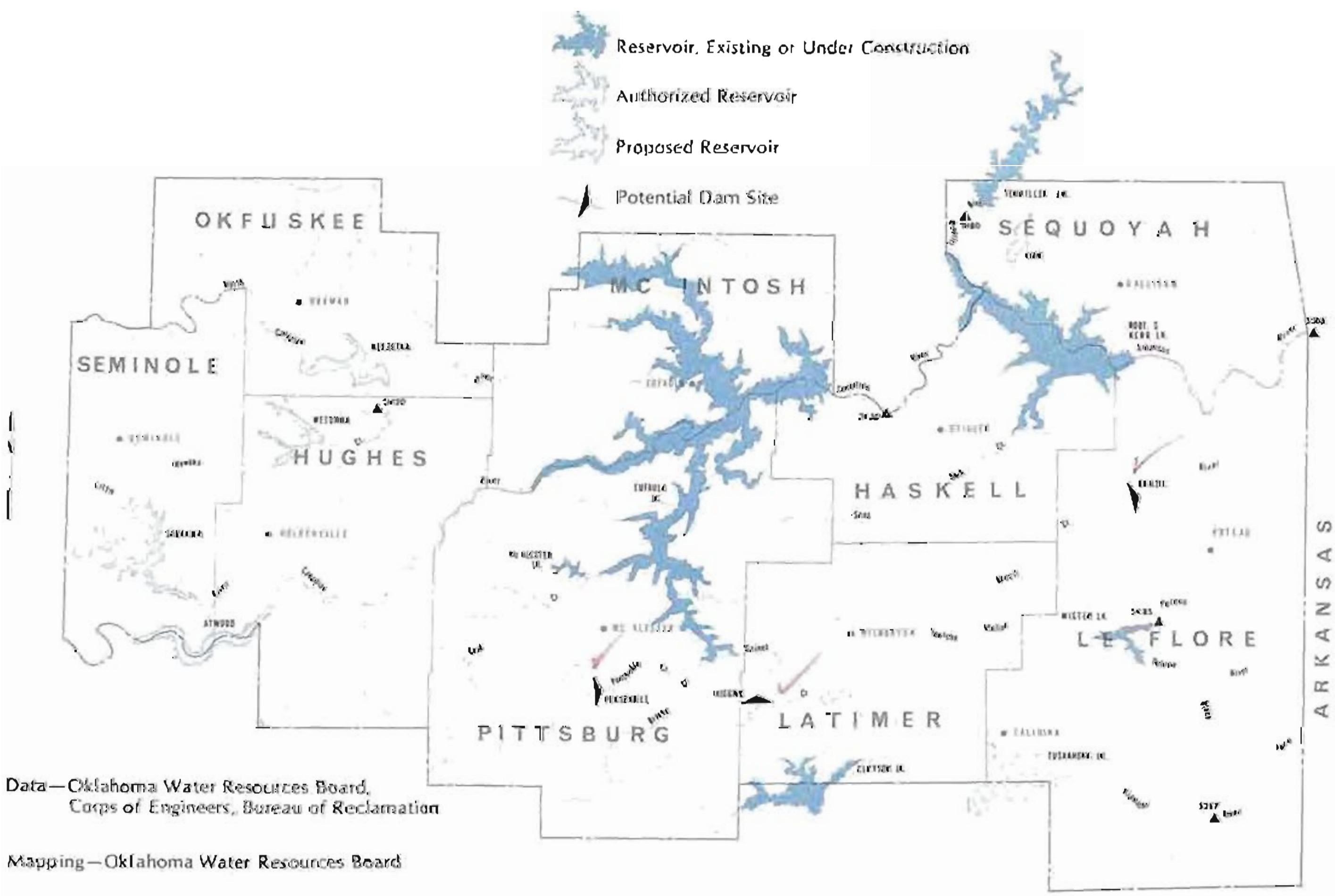


FIGURE 71 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
M & I Water Supply System			
Water Supply Storage	$149,000	$ 460	$ 8,290
Ground Water Development	1,450	170	240
Water Conveyance Facilities	55,700	3,790	7,180
Subtotal	$206,150	$4,420	$15,710
Irrigation Water Supply System			
Water Supply Storage[4]	$ 11,870	$ 12	$ 905
Distribution Facilities	25,800	210	1,925
Subtotal	$ 37,670	$ 222	$ 2,830
TOTAL	$243,820	$4,642	$18,540

[1]Based on January 1978 prices.

[2]Energy costs computed at a 30-mil power rate.

[3]Includes interest and amortization as well as annual OMR&E expenses.

[4]Includes $4,470,000 in construction cost for irrigation storage in potential SCS lakes, $2,000 annual OMR&E and $340,000 total average annual equivalent cost.

FIGURE 72 SURPLUS WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Total Yield	Local Allocation	Potential Surplus
Eufaula	56.0	12.3	43.7
Tenkiller	410.1[1]	214.8[2]	195.2
Tuskahoma	0.7[3]	0.7	—
Atwood	44.8	44.8	—
Sasakwa	135.5	135.5	—
Weleetka	35.8	35.8	—
Welty	4.4[4]	4.4	—
Wetumka	23.9	21.1	2.8
Wister (Modification)	151.2	19.0	132.2
Ground Water & SCS & Municipal Lakes	578.8	63.1	515.7
Subtotal	1441.1	551.5[5]	889.6
Other Potential Sources			
Brazil	87.4	—	87.4
Brushy	9.0	—	9.0
Higgins	68.4	—	68.4
Peaceable	33.6	—	33.6
Wister Modification (Phases 2 & 3)	318.1	—	318.1
Subtotal	516.5	—	516.5
TOTAL	1957.6	551.5	1406.1

[1]Estimated yield from reallocation of hydropower storage to water supply storage.

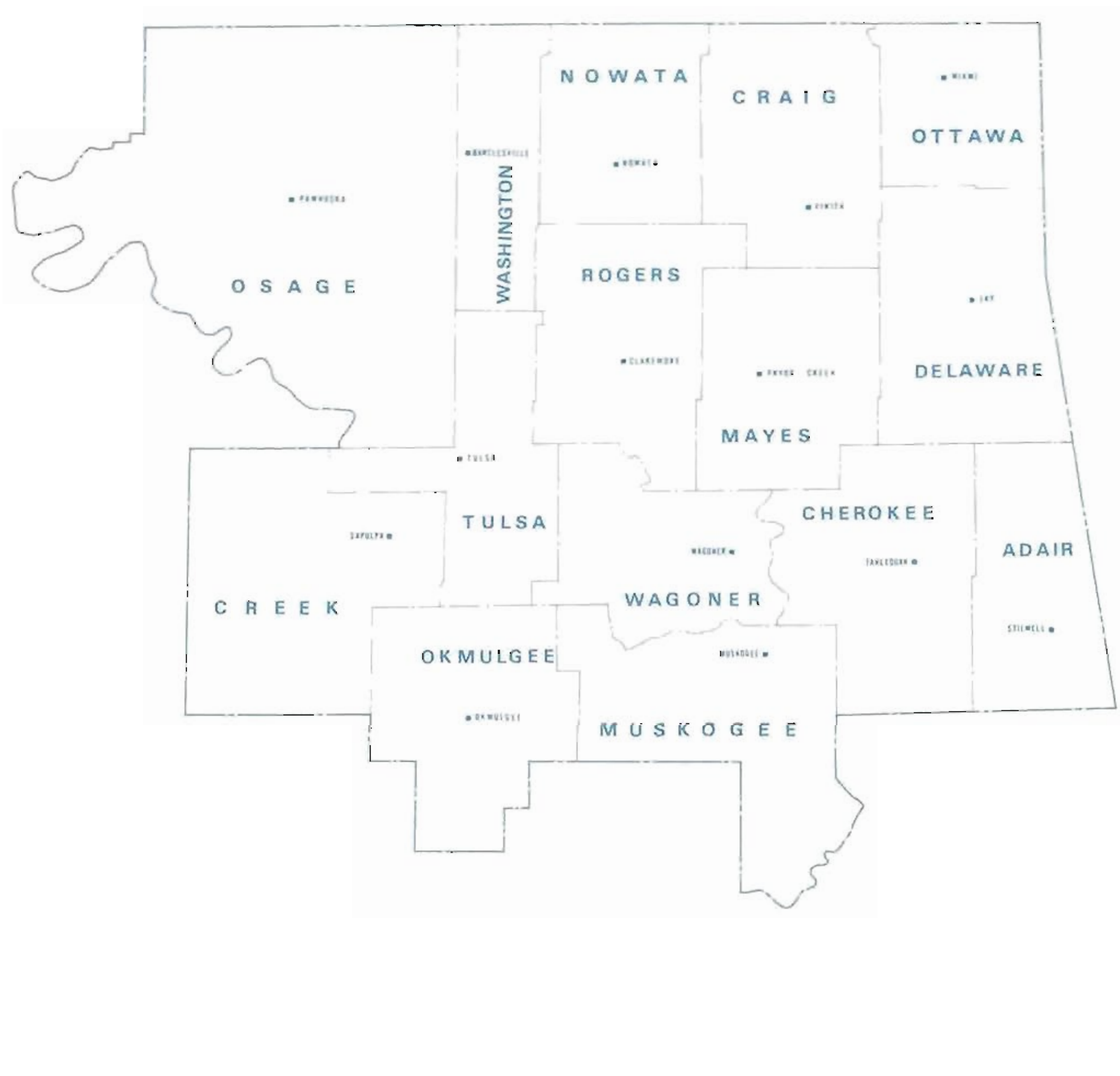
[2]186,500 acre-feet per year of local allocation is for the Northeast Planning Region (28,300 acre-feet per year is allocated to east central region.)

[3]Reflects allocated yield to east central region.

[4]Yield depends on surface water available from Arkansas River.

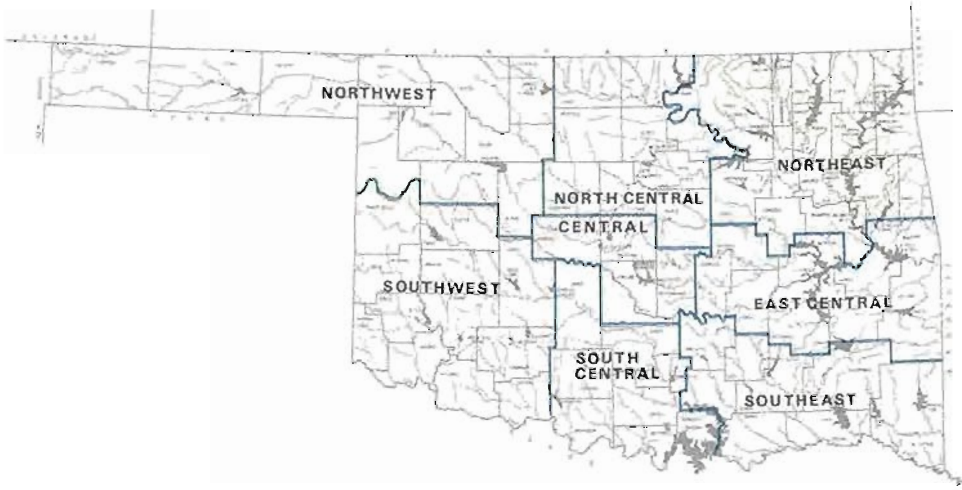
[5]Includes 186,500 acre-feet per year allocation to northeast region.

NORTHEAST PLANNING REGION



Bordered by Kansas on the north and Arkansas and Missouri on the east, the Northeast Planning Region is composed of 15 counties — Adair, Cherokee, Craig, Creek, Delaware, Mayes, Muskogee, Nowata, Okmulgee, Osage, Ottawa, Rogers, Tulsa, Wagoner and Washington. The eastern counties are distinguished by densely forested mountains, the southern counties by wide alluvial plains along the banks of the Arkansas River, and the northwestern portion by low rolling hills. Elevations range from 1,750 feet above mean sea level in Adair County to 400 feet near the Arkansas River. The region covers 11,794 square miles and is drained by the Arkansas, Caney, Verdigris, Deep Fork, Illinois and Grand (Neosho) Rivers.

The Northeast Planning Region experienced an increase in population from 798,389 in 1970 to 877,800 in 1977, very close to the 10 percent rate of increase registered by the entire state. During the same period per capita personal income rose from $2,910 to $5,596, while average covered employment increased from 105,377 to 287,282; these escalations reflecting the strong economic base of the region. Rapid industrial growth has permitted the region to develop richly in terms of human and natural resources. Wholesale and retail trade, oil and gas activities, manufacturing, services and construction contribute to the economic vitality of these 15 counties.



The Northeast Planning Region appears to have a promising economic future due to its abundant supply of oil, gas, water, land and people. Unemployment rates for the region have been moderate over the last few years, declining to 4.4 percent in 1978. A strong labor force should continue to provide the human resources necessary to develop the area's vast natural resources and promote overall social and economic development.

The moist climate in the region varies from humid in the east to subhumid in the west. Spring and fall months are mild with warm days and pleasant nights, and summers are long and usually moderate. Winters are comparatively mild, but on occasion, brief periods of extremely cold weather have been recorded. Average annual lake evaporation slightly exceeds precipitation, ranging from 56 inches in the west to 46 inches in the extreme northeastern corner. Strong southerly winds contribute significantly to this evaporation rate. Mean annual temperatures vary from 59° in the eastern portion to 61° F in the west.

The length of the growing season averages 195 days. As shown in Figure 8, average annual precipitation measures approximately 34 inches in the extreme west to 44 inches in Adair County. Maximum precipitation occurs in the late spring and early summer, with May being the wettest month of the year. Average annual snowfall amounts to slightly over eight inches in the region.

In May 1943, some areas of the Neosho and Arkansas River basins received up to 16 inches of rain in a 2-day period, causing the Arkansas to rise six feet over flood stage at Muskogee. In some areas the water rose 40 feet, covering 2-story buildings and drowning 23 people. The same waters destroyed 90 percent of the area's crops. Clean water and food supplies were scarce, and typhoid posed a threat in many communities. In 1972 severe flooding on the Spring River in the northeast corner resulted in heavy damages. Again in 1973 rainfall amounts over five inches caused the Neosho River to rise one to eight feet above flood stage, inundating several thousand acres of land. In the fall of 1974 heavy rains caused waters to rise 10 to 14 feet above flood stage on Bird Creek, Black Bear Creek, Polecat Creek and Little Caney River and resulted in the loss of two lives and $10 million in damages. Severe flooding of the "150-year frequency" occurred on Pryor Creek in September 1975, when 8.5 inches of rain damaged 30 homes and caused $300,000 in property losses. Mingo, Fred and Joe Creeks rose 19.5 feet above flood stage in May 1976, when 11-inch rains were recorded. This "150-year" flood destroyed 255 houses and 100 mobile homes and inflicted damage to another 290 mobile homes, 30 businesses and 416 apartment units. The 1976 flood caused three deaths and an estimated $12 million in damages in the area.

The Corps of Engineers and the Soil Conservation Service contribute to control of main stem flooding by providing storage in reservoirs throughout the region. In the future, adequate floodplain zoning practices could prove an effective and inexpensive means to assist in the control of flooding.

WATER RESOURCES

Stream Water

Abundant rainfall and naturally accommodating terrain have fostered the construction of many impoundment structures and produced excellent water supplies and recreational facilities for northeast Oklahoma residents and tourists.

Stream water is of high quality, with the exceptions of some of the region's western streams and the main stem of the Arkansas and its tributaries near Tulsa, where natural and man-made pollutants have somewhat degraded the waters. For water quality analysis data at selected USGS monitoring stations, and for locations of these stations, see Appendix B, Figures 4 and 5 .

Average annual runoff ranges from five inches in the northwest corner to 13 inches in the southeast corner, each year producing approximately 5,445,000 acre-feet of runoff providing vast amounts of water surplus to local requirements. A summary of streamflow records from USGS gaging stations within the region is presented in Appendix B, Figure 2 .

The Arkansas River drainage basin encompasses a large portion of this planning region. In general, the Arkansas' water from Tulsa upstream to the mouth of the Salt Fork fails to meet criteria for municipal or domestic use because of high dissolved mineral content from natural sources upstream and/or improper waste disposal. The quality improves significantly by dilution from intervening runoff as it flows downstream from Keystone Dam. Water quality violations have been noted frequently in the waters around the heavily populated Tulsa area. At Muskogee the quality is suitable for municipal raw water supplies approximately 65 percent of the time.

Grand (Neosho) River exhibits good quality water from Kansas to Fort Gibson Reservoir. Turbidity levels are moderately high in the headwaters, but low below the impoundments, and the water ranges from generally hard to slightly alkaline.

The Caney River and Portions of the Verdigris River and some of their tributaries do not meet accepted water quality standards because of occasional high concentrations of dissolved minerals, however impoundments on these streams will provide raw water of acceptable quality for most purposes. The Verdigris has relatively high quality water in the upper reaches, but quality decreases downstream due to contributions from inferior tributaries such as Bird Creek and the Caney River.

The Bird Creek drainage area includes the northern part of the Tulsa metropolitan area. Water quality problems are attributed to sewage effluent and stormwater runoff which contribute fertilizer, animal feces, certain metals and turbidity. Water running off city streets adds oil, grease, asbestos and lead. Polecat and Snake Creeks exhibit problem pollutants such as biochemicals, suspended and dissolved solids, nutrients, some metals and high pH.

The Deep Fork River in this planning region is very turbid and hard, but dissolved oxygen remains near saturation levels and no toxic metals violations have been noted. Because of higher quality flood flows, impounded water of the Deep Fork should produce raw water acceptable for most purposes.

The Illinois River Basin has very good water which is suitable for most purposes. The Illinois, combined with the Grand (Neosho) River, produces an average of nearly six million acre-feet of usable water annually.

Pryor Creek is the recipient of many industrial discharges and has recently exhibited water quality problems in areas where no water quality violations had been previously observed. Recent discovery of the contaminant polychlorinated biphenyls (PCBs) in bottom-feeding fish and sediments precipitated an intensive investigation which is still underway. Since no continuous water quality

FIGURE 73 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Birch Lake	Birch Creek	WS, FC, WQ, R, FW	39,000	15,200[1]	6,700[1]
Candy Lake+	Candy Creek	WS, FC, R, FW	31,260	43,100	8,620
Copan Lake+	Little Caney River	WS, FC, WQ, R, FW	184,300	33,600[2]	21,300[2]
Eucha Lake	Spavinaw Creek	WS, R	0	79,600	84,000[3]
Fort Gibson Lake	Grand (Neosho) River	FC, P	919,200	0	0
Grand Lake[4]	Grand (Neosho) River	FC, P	525,000	0	0
Heyburn Lake	Polecat Creek	WS, FC, Conservation	48,400	2,000	1,900
Hudson Lake[4]	Grand (Neosho) River	FC, P	244,200	0	0
Hulah Lake	Caney River	WS, FC, low-flow regulation	257,900	27,500[5]	19,000[5]
Oologah Lake	Verdigris River	WS, FC, N	965,600	342,600	172,500
Skiatook Lake	Hominy Creek	WS, FC, WQ, R, FW	182,300	304,800[6]	85,100[6]
Spavinaw Lake	Spavinaw Creek	WS, R	0	30,600	0[3]
Webber's Falls Lock & Dam	Arkansas River	N,P,R,FW	0	0	0
SUBTOTAL			3,397,160	878,500	399,120

(Continued)

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.☐	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		AUTHORIZED			
Sand Lake	Sand Creek	WS, FC, WQ, R, FW	51,700	35,000[7]	13,450[7]
Shidler Lake	Salt Creek	WS, FC, R, FW	49,050	54,900	16,800[8]
SUBTOTAL			100,750	89,900	30,250
TOTAL			3,497,910	968,400	429,370
		POTENTIAL		Conservation Storage	
Big Creek	Big Creek	WS, R	—	—	32,500[9]
Boynton[10]	Cloud Creek	WS, R	—	—	104,800[10]
Chelsea	Pryor Creek	WS, R	—	—	21,300[9]
Eldon[11]	Barren Fork Creek	WS, R	0	280,000	157,900
Fort Gibson Power and Inactive Storage	Grand (Neosho) River	WS, FC, P, R	—	—	223,800[12]
Grand Lake Power and Inactive Storage	Grand (Neosho) River	WS, FC, P	—	—	203,300[13]
Heyburn modification	Polecat Creek	WS, FC, R	70,500	101,500	18,800[14]
Peggs	Spring Creek	WS, R	0	88,000	20,000
Salina	Salina Creek	WS, R	0	73,000	16,000
Sid	Spavinaw Creek	WS, R	0	95,000	20,000
Tahlequah[11]	Illinois River	WS, FC, R	200,000	1,500,000	350,000
Welty[15]	Deep Fork River	WS, R, FW	0	800,000	49,300[15]
TOTAL			270,500	2,937,500	1,217,700
TOTAL YIELD					1,647,070

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

☐Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

+Under Construction.

[1]Includes water quality control storage of 7,600 acre-feet which yields 3,350 acre-feet per year.

[2]Includes water quality control storage of 26,100 acre-feet which yields 17,920 acre-feet per year.

[3]Combined yield of both lakes.

[4]The water of these lakes are under the jurisdiction of the Grand River Dam Authority.

[5]This includes low-flow regulation storage of 7,100 acre-feet which yields 5,040 acre-feet per year.

[6]Includes water quality control storage of 240,000 acre-feet which yields 69,440 acre-feet per year.

[7]Includes water quality control storage of 12,200 acre-feet which yields 4,704 acre-feet per year.

[8]Includes yield of 1,456 acre-feet per year for fish and wildlife releases.

[9]Storage requirements have not been developed. The yields were based on approximately 60% of the average annual streamflow in the drainage area.

[10]Offstream storage reservoir. Yield is developed from surplus flows diverted from the Arkansas River.

[11]These potential sites are located on scenic rivers designated by the State Legislature. The Scenic Rivers Act prohibits the construction of an improvement on a scenic river except as specifically authorized by the Legislature.

[12]Yield that can be developed by converting a portion of the hydro-power storage and inactive storage in Fort Gibson Lake to water supply storage.

[13]Yield that can be developed by converting a portion of the hydro-power storage and inactive storage in Grand Lake to water supply storage.

[14]Additional yield with modification.

[15]Regulating storage reservoir to regulate surplus flows diverted from the Canadian and Arkansas Rivers. The yield of the reservoir can supply 28,100 acre-feet per year of which 23,700 acre-feet per year and 4,400 acre-feet per year is proposed for the Northeast Planning Region and East Central Planning Region respectively.

monitoring stations previously existed on this creek, extremely limited historical data are available.

STREAM WATER DEVELOPMENT

Due to an abundance of good quality water, the Northeast Planning Region has experienced extensive stream water development. Of the 13 major reservoirs existing or under construction, nine are under the jurisdiction of the Corps of Engineers; two are regulated by the Grand River Dam Authority; and two belong to the City of Tulsa.

Major Reservoirs

Birch Lake on Birch Creek in Osage County was completed by the Corps of Engineers in March 1977 for the purposes of flood control, water supply, water quality control, recreation and fish and wildlife. The lake contains 39,000 acre-feet of flood control storage and 15,200 acre-feet of water supply and water quality control storage. The water supply and water quality control storage will yield 6,700 acre-feet annually. Since the water is of excellent quality, it is available for any beneficial use.

The City of Barnsdall has an appropriative right to the water supply yield of the lake and has a contract pending with the Corps to repay the cost of storage

Candy Lake, located on Candy Creek in Osage County, begun by the Corps of Engineers in 1976 and scheduled for completion in 1982, is authorized for flood control, water supply and recreation. The completed reservoir will provide 8,620 acre-feet of water supply annually to local cities, towns and rural water districts, along with 31,260 acre-feet of flood control storage.

The quality of Candy Lake water is anticipated to be excellent and appropriate for any beneficial use. The lake will provide an abundance of recreational opportunities for residents and tourists in northeastern Oklahoma. Water rights to the yield of the lake have been granted to the Cities of Ocheleta and Owasso and Washington County Rural Water District #3.

Copan Lake, under construction by the Corps of Engineers on Little Caney River in northern Washington County, is authorized for water supply, flood control, water quality control, recreation and fish and wildlife propagation. Scheduled for completion in October 1981, it will provide 184,300 acre-feet of flood control storage and 33,600 acre-feet of water supply and water quality control storage. Dependable annual yield from the reservoir will be 21,300 acre-feet. Water rights to the full water supply yield of the lake are held by the City of Copan and Public Service Company of Oklahoma.

Fort Gibson Lake, on the Grand (Neosho) River, was completed by the Corps of Engineers in 1953, authorized for flood control and hydroelectric power generation. The reservoir provides 919,200 acre-feet of flood control storage. The hydroelectric power plant has four generators with a capacity of 11,250 kilowatts each, with potential for the installation of two additional units.

The Corps recently has been considering adding more power units and/or providing for water supply in the lake. As planning studies continue, the feasibility of these and other alternatives will be assessed.

Heyburn Lake on Polecat Creek southwest of Sapulpa, was completed by the Corps of Engineers in 1950 for the purposes of flood control and conservation storage. The lake provides 48,410 acre-feet of flood control storage. Two thousand acre-feet of water supply storage in the lake will yield 1,900 acre-feet annually. Water rights have been appropriated to Creek County Rural Water District #1, which sells water to Rural Water District #2 to supply Glenpool and Kiefer, and to Rural Water District #3.

Water quality of Heyburn is excellent and the lake is a reliable source of water.

Hulah Lake on the Caney River in far north Osage County, was completed by the Corps of Engineers in 1951 for the authorized purposes of flood control, water supply, low flow regulation and other conservation purposes. The lake contains 257,900 acre-feet of flood control storage and provides 30,300 acre-feet of conservation storage. Hulah Lake's water supply yield of nearly 14,000 acre-feet makes municipal and industrial water available to the local area. The City of Bartlesville and the Hulah Rural Water District have water rights to the lake.

Present water quality of Hulah Lake is excellent, however surveillance of oil field operations and control over waste discharges must continue in order to prevent pollution.

Oologah Lake was built by the Corps in two phases, with the first phase completed in 1963 and the second in 1974. The project, located on the Verdigris River in northern Rogers County, was authorized for flood control, water supply and navigation. Flood control storage in the project is 965,600 acre-feet, with 342,600 acre-feet allocated for water supply, 168,000 acre-feet for navigation and 33,500 acre-feet for 50 years' sediment. Water supply yield from the project is 172,500 acre-feet. The City of Tulsa holds a majority of the water rights for municipal and industrial uses. Other water rights holders include Collinsville, Chelsea, Public Service Company, Nowata Rural Water District #1 and Rogers County Rural Water Districts #1 and #2. Water quality of Oologah is fair and the water must be treated to make it suitable for municipal use.

Skiatook Lake on Hominy Creek near the City of Skiatook was begun by the Corps of Engineers in 1974 for the purposes of flood control, water supply, water quality control, recreation and fish and wildlife. Scheduled for completion in 1982, the flood control storage in Skiatook Lake will be 182,300 acre-feet, with conservation storage of 319,400 acre-feet. The lake contains water supply storage for 15,680 acre-feet of water supply yield and 69,440 acre-feet yield from water quality control storage. The water supply storage yield of the lake has been fully appropriated to the Cities of Skiatook and Sand Springs, Sperry-

Avant-Ramona and Washington County Rural Water District #3. Water rights have also been issued to the City of Sapulpa, Public Service Company and Rogers County Rural Water District #4 from the water quality control storage. The use of this water is contingent upon Congressional reallocation of the water quality control storage to water supply storage.

The quality of water in Skiatook Lake will meet drinking water standards except during periods of low inflows.

Webbers Falls Dam and Lock is an integral component of the McClellan-Kerr Navigation System on the Arkansas River. Begun in 1955, the project was completed in 1970 for the purposes of navigation and hydroelectric power generation, which began in July 1973 and developed a total capacity of 60,000 kilowatts from three units. Average potential power generating capacity is 213,300,000 kwh per year.

Grand Lake o' the Cherokees on the Grand (Neosho) River in far northeastern Oklahoma was constructed by, and remains under the jurisdiction of, the Grand River Dam Authority for the purposes of flood control, hydroelectric power and recreation. Completed in 1940, the huge reservoir spans three counties and is a major recreational attraction. Flood control storage contains 525,000 acre-feet, along with 1,192,000 acre-feet of power storage.

Wash Hudson Lake (Markham Ferry Reservoir) on the Grand (Neosho) River, was completed by the Grand River Dam Authority in 1964. Authorized purposes of the project are flood control and hydroelectric power. The lake contains 244,200 acre-feet of flood control storage and 200,300 acre-feet of run-of-the-river water for power production. Lake Hudson is operated by the GRDA in conjunction with Grand Lake upstream and Fort Gibson Lake downstream for power production.

Major Municipal Lakes

There are two major municipal lakes in the Northeast Planning Region, both built and maintained by the City of Tulsa.

Spavinaw Lake, on Spavinaw Creek, the smaller of Tulsa's two municipal lakes, has a conservation storage capacity of 30,600 acre-feet. Completed in 1924, Spavinaw was the first major transbasin water supply facility constructed in Oklahoma.

Eucha Lake was constructed in 1952 as a municipal water supply reservoir on Spavinaw Creek in Delaware County to augment the storage of Spavinaw Lake, which is located three miles downstream from Eucha. Conservation storage is 79,600 acre-feet with a maximum combined yield of 112,000 acre-feet from Eucha and Spavinaw. The excellent quality water is transported to Tulsa via two pipelines.

Soil Conservation Service Projects

The Soil Conservation Service has 39 watershed projects in this 15-county region designed for the purpose of providing watershed protection and flood prevention as well as providing municipal and industrial water. Local residents and tourists utilize these lakes for recreation, and the Cities of Stilwell and Okmulgee use them for the storage of supplemental water supplies.

Thirteen of the projects are complete or under construction, 17 are planned and the remaining nine have a potential for development. Multipurpose sites are designated as potential municipal water sources for the towns of Foraker, Grainola, Ramona, Bristow, Dewey and Wann.

Authorized Development

There are two water resource projects in the Northeast Planning Region, Sand and Shidler Lakes, authorized for construction by the Corps of Engineers. Upon their completion the lakes will provide a total annual water supply yield of approximately 24,000 acre-feet.

Sand Lake will be located on Sand Creek in Osage County nine miles west of Bartlesville and is authorized for flood control, water supply, water quality, recreation and fish and wildlife. Conservation storage in the lake will be 35,000 acre-feet, with flood control storage of 51,700 acre-feet. The conservation storage will provide a dependable 13,450 acre-feet per year. The City of Bartlesville has the water rights to the yield from the reservoir. The quality of water would be satisfactory for municipal and industrial use after normal treatment.

Shidler Lake was authorized for the purposes of flood control, water supply, recreation and low flow augmentation. The dam will be located on Salt Creek in far southwestern Osage County. The lake is expected to provide 49,050 acre-feet of flood control storage and 15,344 acre-feet per year of dependable water supply yield.

Preconstruction planning has been completed, and the Corps awaits Congressional funding for construction Water impounded by the project would be of fair quality, suitable for most beneficial uses.

Potential Development

Although numerous reservoirs have been developed utilizing the most suitable dam sites, the favorable climate and topography of the Northeast Planning Region create almost unlimited potential for further development, with those sites listed in Figure 73 considered the most promising. A large portion of the existing reservoir development is authorized for hydroelectic power generation, but the increasing demand for municipal and industrial water supplies may in the future justify the conversion of a portion of the hydroelectric power storage to municipal and industrial storage. The potential water supply development from hydroelectric power conversion in existing reservoirs is shown in the same figure.

STREAM WATER RIGHTS

As of February 20, 1979 there had been issued 592 vested stream water rights and permits for the appropriation of 774,504 acre-feet of water per year in the region. See Figure 74 .

FIGURE 74 STREAM WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Adair	6	13,850	3	6,611	115	22,597	—	—	1	16	2	1,060	127	44,134
Cherokee	8	34,831	1	420	41	8,833	—	—	32	1,341	8	1,347	90	46,772
Craig	1	3,620	—	—	—	—	—	—	—	—	—	—	1	3,620
Creek	10	35,800	1	7,511	8	4,167	1	565	2	1,250	—	—	22	49,293
Delaware	1	2,000	—	—	13	2,806	—	—	1	850	—	—	15	5,656
Mayes	3	2,382	—	—	2	160	—	—	—	—	—	—	5	2,542
Muskogee	4	37,620	5	144,581	27	8,664	—	—	—	—	—	—	36	190,865
Nowata	5	6,856	1	27,922	5	886	5	1,140	—	—	—	—	16	36,804
Okmulgee	6	24,168	—	—	7	2,694	3	4,010	—	—	—	—	16	30,872
Osage	26	93,059	4	31,025	39	12,112	3	3,740	4	278	3	440	79	140,654
Ottawa	—	—	—	—	2	280	—	—	—	—	—	—	2	280
Rogers	14	28,552	8	40,644	36	12,213	2	505	10	6,900	2	650	72	89,464
Tulsa	2	7,112	3	26,800	19	1,459	3	2,915	3	178	1	780	31	39,244
Wagoner	7	27,097	1	1,378	22	10,374	1	272	1	40	1	83	33	39,244
Washington	6	42,979	—	—	36	10,812	2	582	1	450	2	237	47	55,060
Total	99	359,926	27	286,892	372	98,057	20	13,729	55	11,303	19	4,597	592	774,504

Ground Water

Major ground water basins in the region are the Roubidoux and Vamoosa Formations and alluvium deposits. See Figure 28 .

Because of their insignificant yields, the Noxie Sandstone, Keokuk and Reeds Springs Formations are considered of minor importance and are not included in this discussion.

See Figure 29 for estimated total water in storage and amounts recoverable from ground water basins in the Northeast Planning Region.

Roubidoux (Upper Cambrian-Lower Ordovician) consists mainly of sandy and cherty dolomite. The Roubidoux basin is generally considered to include the Roubidoux, Gasconade and Eminence-Potosi Formations, of which the Roubidoux is the principal water-bearing unit. It does not outcrop at the surface, but is buried at depths of 450 to 1,700 feet beneath Ottawa and Delaware Counties, and under small parts of Craig and Adair Counties. The artesian or confined water is under sufficient pressure to cause it to rise above the surface. With pumpage over time, the artesian head has declined, requiring the water to be lifted more than 500 feet to the surface in some wells. Yields are as great as 1,000 gpm and average 200 gpm. Although the water is hard, it has a low total mineral content. The water quality in Ottawa County is of a calcium bicarbonate type and suitable for most purposes, but farther west, it changes to sodium chloride and becomes unusable.

Vamoosa Formation (Upper Pennsylvanian) outcrops in a band four to nine miles wide across Osage and Creek Counties. It is composed of interbedded sandstone, shale and conglomerate, with the proportion of shale increasing northward. The formation ranges from about 300 to more than 630 feet thick. The large amount of shale in northern portions of the Vamoosa limits well yields to about 60 gpm, and a major water quality problem is brine infiltration from oilfield operations.

Alluvium deposits (Quaternary) are stream-laid deposits of interfingering sand, silt and clay. The most productive deposits lie along the Arkansas River in a band ranging in width from one to six miles. Near Tulsa, the alluvium is about 30 feet thick, while downstream around Webbers Falls, thickness is approximately 55 feet. Yields range from 20 to 400 gpm, with wells penetrating the sand layers having the greatest yield. Variations in yield depend on well depth as well as size and method of well construction. Water in the alluvium is classified as hard to very hard, with dissolved solids content in excess of 500 mg/L in some places. The water is generally of a sodium or calcium bicarbonate type.

GROUND WATER DEVELOPMENT

The Roubidoux is the most significant aquifer in the Northeast Planning Region, yielding great amounts of ground water to the cities, towns and industries along northern Oklahoma's Missouri and Arkansas borders. It provides municipal supplies to Miami, Afton, Fairland, Bluejacket, Welch, Picher, Quapaw and Commerce, as well as water to extensive mining operations and other industries in the area.

Recharge to the Roubidoux aquifer is in Missouri, and structural features such as faults obstruct the flow of the recharge, resulting in increasing drawdowns in pumped wells. Large drawdowns and declining water levels have made it necessary to lower pumps or deepen wells to attain adequate yields. Although a large amount of water is available in the aquifer, its cost is driven progressively higher by increased pumping lifts.

The alluvium and terrace deposits along the Arkansas River yield large amounts of water, especially in Muskogee, Tulsa, Wagoner and

Osage Counties. Potential exists for expanded development.

The Vamoosa aquifer is a potential source of large amounts of water, however the areas that exhibit the greatest potential are not located near the cities and towns which require large quantities of water. The Cities of Oilton, Bristow and Drumright utilize ground water from the Vamoosa for municipal and industrial supplies. Compared to the amount of water in storage and the annual rate of recharge, the amount of water withdrawn for municipal and irrigation use is insignificant.

GROUND WATER RIGHTS

As of July 1979, 187 ground water permits had been issued in the region, allocating fresh ground water for municipal, industrial, irrigation and other beneficial uses. See Figure 76 .

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Northeast Planning Region is currently using an estimated 307,300 acre-feet of water annually. Municipal use consumes the greatest amount of water, with industrial needs a close second. Irrigation and power needs require significantly smaller amounts as indicated in Figure 75 . Projections indicate that the area will require a total of 971,000 acre-feet per year by 2040 with the majority of the increase to meet additional municipal and power needs.

Population figures in 1977 revealed that 877,800 citizens resided in the Northeast Planning Region, and projections indicate that 1,664,200 persons may reside in the 15-county region by the year 2040. As a result of this increase, municipal water demands, which include rural water needs, are expected to grow from the present 119,400 acre-feet per year to 349,000 acre-feet per year. The Cities of Muskogee, Tulsa, Broken Arrow, Bartlesville and Sapulpa are expected to experience the greatest population growth and hence, the largest increases in demand.

One hundred nine rural water districts presently serve the region and obtain their water supplies from both ground water basins and area streams. Projections indicate that rural needs will increase substantially in the future.

Industrial uses currently demand 104,900 acre-feet per year, a figure projected to rise to 187,500 acre-feet annually by 2040. The largest industrial water users are oil and gas refineries and coal mining operations, both water-intensive industries. It is anticipated that 33,600 acre-feet per year of this demand can be met by recycled wastewater.

Utility water requirements in the area are presently 57,000 acre-feet per year. Oklahoma Gas and Electric Company operates two plants in the area with a net generating capacity of

FIGURE 75 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	119.4	179.2	219.4	248.5	278.6	309.0	349.0
Industrial	104.9	140.1	158.6	172.8	177.9	183.1	187.5
Power	57.0	146.1	197.0	241.4	285.6	311.7	338.9
Irrigation	26.0	51.0	60.4	70.3	80.0	87.9	95.6
Total	307.3	516.4	635.4	733.0	822.1	891.7	971.0

FIGURE 76 GROUND WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Adair	1	320	—	—	3	633	—	—	3	3	—	—	7	956
Cherokee	—	—	—	—	3	144	—	—	2	2	—	—	5	146
Craig	2	70	1	56	—	—	—	—	—	— —	—	—	3	126
Creek	3	1,724	7	3,227	2	206	10	1,996	—	—	—	—	22	7,153
Delaware	3	176	—	—	1	200	—	—	2	1123	—	—	6	1,499
Mayes	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Muskogee	1	500	2	382	16	5,890	—	—	1	80	—	—	20	6,852
Nowata	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Okmulgee	—	—	—	—	—	—	2	2,914	—	—	—	—	2	2,914
Osage	5	5,512	2	12,275	30	10,915	3	738	3	47	—	—	43	29,487
Ottawa	25	16,195	2	1,191	4	750	—	—	—	—	—	—	31	18,136
Rogers	—	—	—	—	—	—	1	56	—	—	—	—	1	56
Tulsa	3	1,273	2	821	19	3,632	1	14,100	3	750	—	—	28	20,576
Wagoner	—	—	—	—	19	4,426	—	—	—	—	—	—	19	4,426
Washington	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Total	43	25,770	16	17,952	97	26,796	17	19,804	19	2,005		0	187	92,327

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

1,279 megawatts, and an additional plant is under construction. Public Service Company of Oklahoma operates three plants with a combined capacity of 2,770 megawatts. In addition, the Grand River Dam Authority has one existing plant and one under construction, with the total capacity of the two plants being 540 megawatts. It is projected that the demand for water for cooling purposes will increase to 338,900 acre-feet per year.

Present irrigation water needs are 26,000 acre-feet per year for the irrigation of 24,555 acres on 194 farms. Projections indicate that the area will be irrigating 95,600 acres by 2040, requiring 95,600 acre-feet of water annually. Due to abundant rainfall in this area, irrigation water is normally utilized only as a supplemental water supply.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

The Northeast Planning Region experiences generous rainfall and runoff, which present the area with excellent potential for water resources development. The region has many existing major reservoirs and smaller lakes which provide good quality water. However, the area continues to suffer from inadequate distribution facilities, with many people not served by a dependable water system, and flooding remains a frequent problem. Although progress has been made in harnessing the region's raging waters, many areas still need additional flood control and increased amounts of improved quality water.

Existing ground and surface water supplies in the area can provide 302,000 acre-feet per year. Proposed development could supply the additional water to meet 2040 requirements and, as Figure 77 shows, still have a potential surplus in excess of 1.3 million acre-feet per year. With the addition of other potential sources not considered in the plan, a total annual surplus of over two million acre-feet could be developed.

As a part of the Oklahoma Comprehensive Water Plan, it is proposed that the region expand the use of existing sources and develop additional local sources to meet projected water needs. See Figure 80 Existing reservoirs such as Grand, Fort Gibson and Tenkiller would require a reallocation of hydropower and inactive storage to water supply storage. Existing law requires the Grand River Dam Authority to provide future water supplies to cities and towns in the Grand (Neosho) River Basin. The use of Fort Gibson and Tenkiller Lakes would require Congressional authorization for reallocation to water supply storage. The small amounts of water supply storage presently available in Tenkiller would have to be greatly expanded.

Proposed reservoirs include Welty and Sid Lakes, with Welty also serving the East Central Planning Region. Additional ground water development and new SCS lakes are also proposed to supply additional quantities of water.

Figure 79 shows the 15 counties, planned supplies and projected 2040 water demands. As indicated, supplies would equal or exceed demands in all counties. A total of 95,600 acres is projected to be irrigated based upon one acre-foot of water per acre.

Preliminary cost estimates for the proposed development are shown in Figure 78 . Total construction cost is estimated at $375 million, with an average annual equivalent cost of $41

FIGURE 77 SURPLUS WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Total Yield	Local Allocation	Potential Surplus
Birch	6.7	6.7	—
Candy	8.6	6.5	2.1
Copan	15.0	15.0	—
Eufaula	3.7[1]	3.7	—
Fort Gibson	223.8	107.0	116.8
Grand	203.3	83.6	119.7
Hulah	19.0	19.0	—
Oologah	172.8	172.8	—
Skiatook	73.9	73.0	0.9
Spavinaw[2]	84.0	84.0	—
Tenkiller[1]	186.5	186.5	—
Sand	13.4	13.4	—
Shidler	15.3	2.1	13.2
Sid	20.0	4.0	16.0
Welty	49.3	23.7	25.6
Ground Water & SCS & Municipal Lakes[3]	1234.2	173.0	1061.2
Subtotal	2329.5	974.0	1355.5
Other Potential Sources			
Heyburn (Modification)	20.7	—	20.7
Big Creek	32.5	—	32.5
Boynton	104.8	—	104.8
Chelsea	21.3	—	21.3
Eldon	157.9	—	157.9
Greasy	10.1	—	10.1
Peggs	20.0	—	20.0
Salina	16.0	—	16.0
Tahlequah	350.0	—	350.0
Subtotal	733.3	—	733.3
TOTAL	3062.8	974.0	2088.8

[1]Reflects allocated yield to Northeast Planning Region.

[2]Includes yield of Eucha Lake.

[3]Includes 28,000 acre-feet per year from wastewater reuse and existing municipal sources, with the exception of existing supplies from major reservoirs, which are included in the local allocation for each existing reservoir listed, and with the exception of Spavinaw Lake (listed separately).

million. Costs of the municipal and industrial water supply system are estimated at approximately $363 million for storage and conveyance facilities. Annual OMR&E costs are $14 million for storage facilities and $40 million for conveyance facilities.

The cost for developing irrigation sources is estimated at $12 million, with an annual OMR&E cost of $94,000 and a total average annual equivalent cost of $960,000. These costs include storage in SCS lakes and new ground water development. The cost of distribution facilities is not included here, but should be addressed in future planning.

FIGURE 78 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
M & I Water Supply System			
Water Supply Storage	$121,000	$ 3,810	$12,880
Water Conveyance Facilities	242,000	10,580	27,480
Subtotal	$363,000	$14,390	$40,360
Irrigation System			
Water Supply Storage[4]	$ 8,570	$ 4	$ 650
Ground Water Development	3,370	90	310
Subtotal	$ 11,940	$ 94	$ 960
TOTAL	$374,940	$14,484	$41,320

[1]Based on January 1978 prices
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Estimated cost of irrigation storage in an SCS multipurpose lake.

FIGURE 79 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Adair	Cherokee	Craig	Creek	Delaware	Mayes	Muskogee	Nowata	Okmulgee	Osage	Ottawa	Rogers	Tulsa	Wagoner	Washington	Total Supply
Municipal and Industrial Component[1]																
Ground Water & SCS & Municipal Lakes[2]	—	—	—	2.2	0.1	—	11.4	2.0[5]	8.8	5.0	—	6.7	153.8[3]	—	11.2	201.7
Birch	—	—	—	—	—	—	—	—	—	1.9	—	4.8	—	—	—	6.7
Candy	—	—	—	—	—	—	—	—	—	—	—	5.2	—	—	1.3	6.5
Copan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15.0	15.0
Eufaula	—	—	—	—	—	—	1.3	—	2.4	—	—	—	—	—	—	3.7
Fort Gibson	—	0.2	—	—	—	—	4.4	—	—	—	—	—	86.5	15.9	—	107.0
Grand	—	—	5.7	—	4.6	35.2	—	—	—	—	15.0	—	16.8	6.3	—	83.6
Hulah	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7.7	7.7
Oologah	—	—	—	—	—	—	—	3.5	—	—	—	77.4	54.5	—	—	135.4
Skiatook	—	—	—	10.3	—	—	—	—	—	2.6	—	6.7	53.4	—	—	73.0
Tenkiller	11.9	11.5	—	—	—	—	163.1	—	—	—	—	—	—	—	—	186.5
Sand	—	—	—	—	—	—	—	—	—	1.8	—	0.2	—	—	11.4	13.4
Shidler	—	—	—	—	—	—	—	—	—	2.1	—	—	—	—	—	2.1
Sid	—	—	—	—	4.0	—	—	—	—	—	—	—	—	—	—	4.0
Welty	—	—	—	9.4	—	—	—	—	14.3	—	—	—	—	—	—	23.7
Adjacent County[4]	—	—	—	—	—	—	8.2	—	0.5	—	—	—	—	0.2	—	8.9
M & I Supply	11.9	11.7	5.7	21.9	8.7	35.2	188.4	5.5	26.0	13.4	15.0	101.0	365.0	22.4	46.6	878.4
Irrigation Component																
Ground Water & SCS Lakes	8.3	6.8	4.6	5.6	2.7	3.5	21.3	2.7	1.8	18.2	1.6	2.4	5.6	6.1	4.4	95.6
Irrigation Supply	8.3	6.8	4.6	5.6	2.7	3.5	21.3	2.7	1.8	18.2	1.6	2.4	5.6	6.1	4.4	95.6
TOTAL LOCAL SUPPLY	20.2	18.5	10.3	27.5	11.4	38.7	209.7	8.2	27.8	31.6	16.6	103.4	370.6	28.5	51.0	974.0
2040 DEMAND	20.2	18.5	10.3	26.4	11.3	37.6	209.7	8.2	27.8	31.6	16.2	103.3	370.4	28.5	51.0	971.0

[1]Includes cooling water (power) demands
[2]Includes present use from existing federal reservoirs
[3]Includes 84,000 acre-feet per year from Spavinaw and Eucha Lakes, 28,000 acre-feet per year from wastewater reuse and 37,400 acre-feet per year from Oologah Reservoir
[4]Source of supply from a county in the East Central Planning Region
[5]Provided by Coffeyville, Kansas

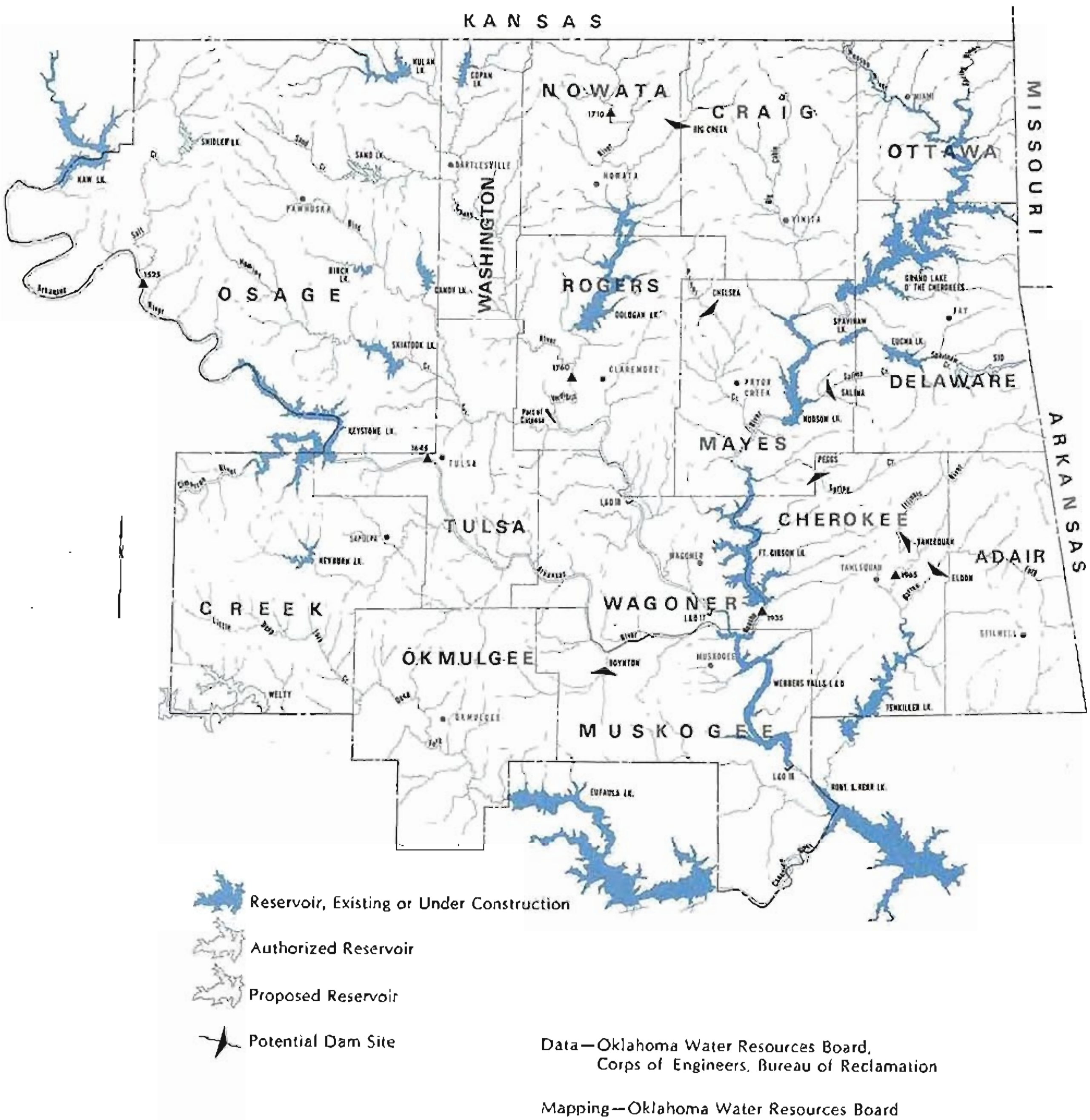
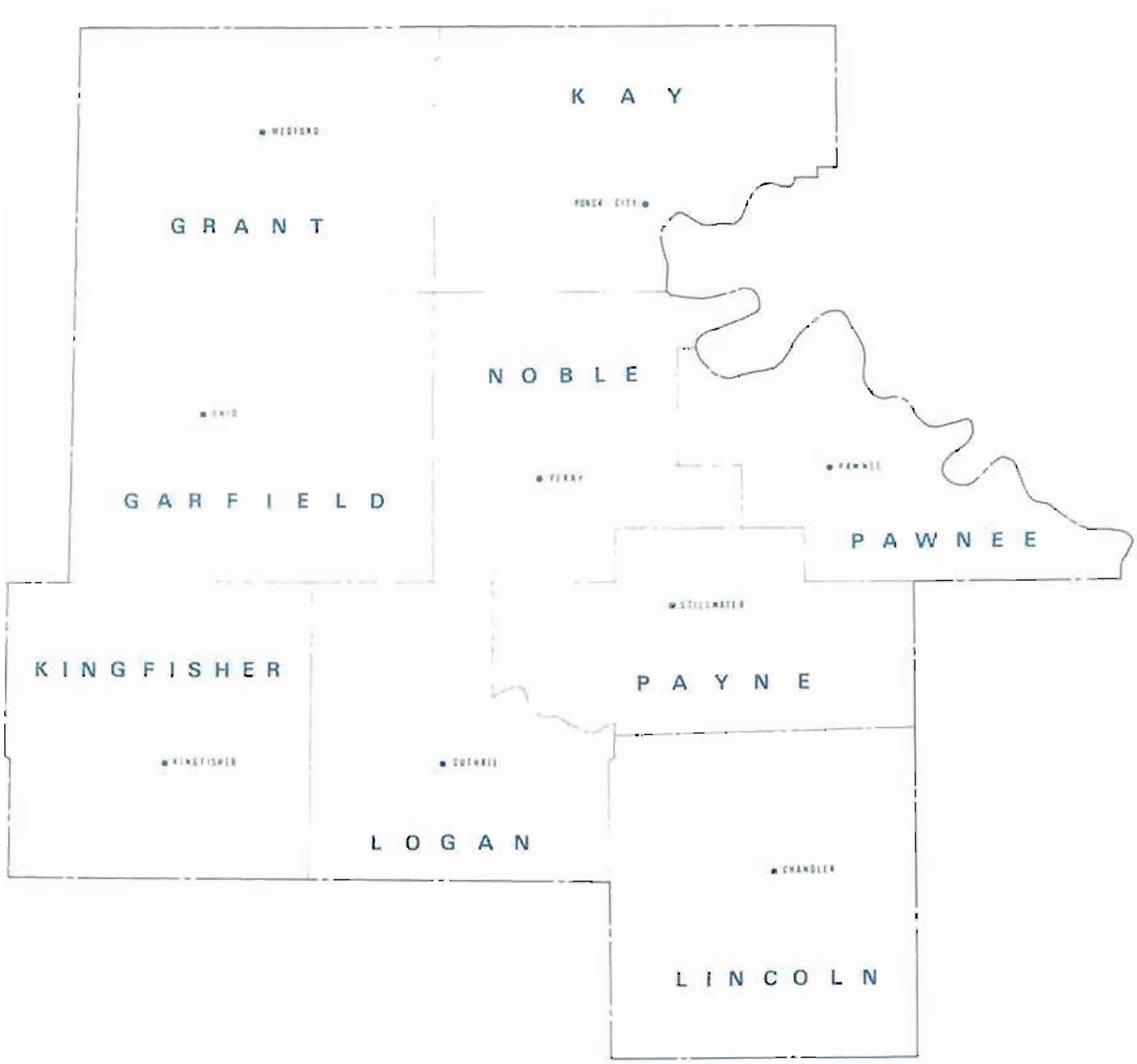
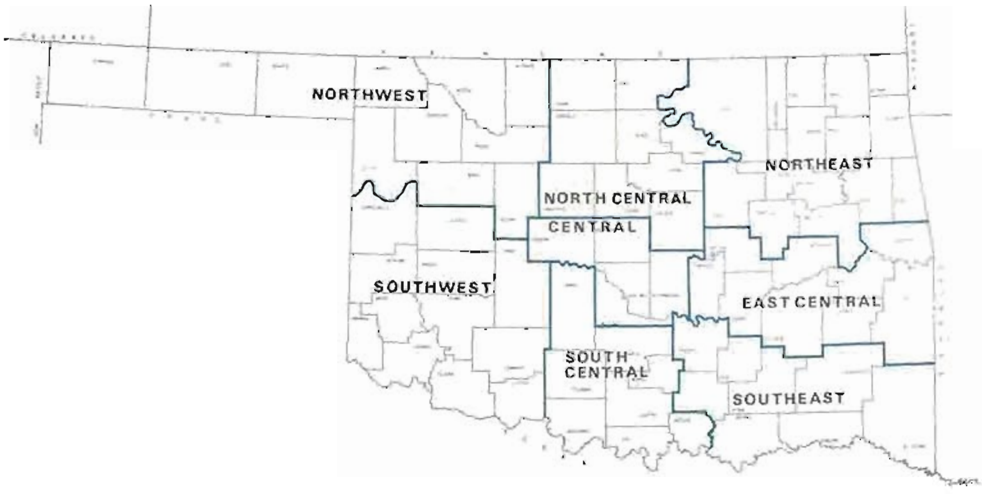


FIGURE 80 PROPOSED PLAN OF DEVELOPMENT

NORTH CENTRAL PLANNING REGION



The North Central Planning Region covers 7,689 square miles and includes the counties of Garfield, Grant, Kay, Kingfisher, Lincoln, Logan, Noble, Pawnee and Payne.



The region rolls from bare, low sandhills in the west to scrub oak-spattered hills in the center to rough, densely forested hills in the east. Elevations range from 1,100 feet above mean sea level in Grant County to 850 feet in Lincoln County. The Cimarron, Chikaskia, Salt Fork of the Arkansas and the Arkansas Rivers drain the region.

Agriculture is the leading industry, with approximately half of the region's total area either in pastureland for grazing beef and dairy cattle or in cropland for the cultivation of wheat and other grains. All of the North Central Planning Region lies in the southern part of the midwest's wheat belt. Agriculture flourishes in the region, but frequent droughts inflict severe damage to crops. Dependable sources of water must be developed to insure the continued growth and prosperity of the agricultural economy. Oil and gas production is active in all nine counties, but the greatest production is from two giant oil fields, Tonkawa in Kay and Noble Counties and Sooner Trend in Garfield, Kingfisher and Logan Counties.

The population of the 9-county region has increased from 235,292 in 1970 to 262,800 in 1977, a 12 percent rise. During that same period, per capita personal income rose from $3,229 to $5,877 and the average covered employment increased from 37,783 to 66,942. Such increases reflect the region's rapid industrial growth in recent years, with 21 new manufacturing firms locating in the area between 1974 and 1978. Major industry types include wholesale and retail trade, manufacturing and personal services. Growth is most apparent in the area's three largest cities, Enid, Stillwater and Ponca City, which have grown at an average rate of 17 percent since 1970. Since the labor force has grown at a slower rate than that of the general population, the region's unemployment rate has remained among the lowest in the state.

The climate of the North Central Planning Region is moist and subhumid. Average annual lake evaporation greatly exceeds annual precipitation, ranging from 61 inches in the west to 55 inches in the east. See Figure 9 . Mean annual temperatures vary little across the region, from 60° to 61°F. as shown in Figure 7 . The length of the growing season averages approximately 205 days. Annual precipitation ranges from 28 inches in the west to 36 inches in the extreme eastern portion of the region as shown in Figure 8 . Maximum precipitation occurs in the spring and fall, and May is the wettest month of the year. Seventy-five percent of the annual precipitation falls during the 205-day growing season, and thunderstorms often accompanied by high winds and hail occur frequently over the region. Snowfall averages 14 inches annually.

The most severe flooding in the region is the result of sudden, concentrated areas of heavy precipitation that occur over the basin in a short time. In October 1973 a record-breaking 15.68-inch rainfall in a 24-hour period in the Enid area caused severe damage. Seventy-five percent of this amount fell in four hours, with total precipitation exceeding 20 inches reported at some stations. Devastating flooding occurred on the Salt Fork at Tonkawa, where several hundred motorists were stranded when a section of Interstate Highway 35 washed out. Other areas affected by the same storm were Ponca City and Ralston on the Arkansas River, Blackwell on the Chikaskia, and Waynoka, Dover, Guthrie and Perkins on the Cimarron. Tributaries to these streams which overflowed their banks included Skeleton, Black Bear and Red Rock Creeks, and especially Turkey Creek which heavily damaged Dover. Damage estimates reached $30 million in losses to property and agriculture.

In 1974 the Chikaskia again rose to seven feet above flood stage, forcing the evacuation of families from their homes in Blackwell. Black Bear Creek, Deep Fork Creek and other area streams rose 10 to 14 feet over flood stage and disaster relief funds were requested in several of the region's counties. In May 1975, 200 people were driven from their homes by four inches of rain that caused the Cimarron south of Stillwater to rise 3.7 feet. The Soil Conservation Service continues its program of watershed protection and flood prevention with projects planned or under construction in major problem areas of the North Central Planning Region.

WATER RESOURCES

Stream Water

The major streams in the North Central Planning Region are the Cimarron, Salt Fork of the Arkansas and Arkansas Rivers with a combined drainage area of 7,689 square miles.

Average annual runoff from precipitation ranges from about two inches in western Garfield County to five inches along the eastern edge of Pawnee County. See Figure 20 . Approximately 5,000,000 acre-feet of water leaves the North Central Planning Region annually through the Arkansas River. The U.S. Geological Survey maintains 10 streamflow gaging stations in this region which provide data for determining the amount of water available for storage at particular sites and the effects of impoundment structures on downstream flows. See Appendix B, Figure 2 .

Water of the major streams in the region is generally of poor quality and unsuitable for many beneficial purposes. Good quality water in this planning region is confined to the tributaries of the major streams, such as the Chikaskia River tributary of the Salt Fork. For water quality analysis data at selected U.S. Geological Survey monitoring stations and locations of these stations, see Appendix B, Figures 4 and 5 .

The Cimarron River, which flows through Kingfisher, Logan and Payne Counties, has poor water quality due to high nutrient levels contributed by Cottonwood and Skeleton Creeks and heavy mineralization. The poor mineral quality is primarily due to natural chloride pollution in its upper reaches. The river water is very hard with moderate to high turbidity and pH levels sometimes in excess of water quality standards. Dissolved oxygen remains at or near saturation levels, and iron, manganese, lead, silver, cadmium and arsenic are present in elevated concentrations.

Cottonwood Creek, a tributary of the Cimarron River, has poor quality water due to high nutrient levels, high concentrations of iron and manganese and moderate levels of mineralization It is a moderately turbid stream and dissolved oxygen concentrations decrease to near septic conditions during warm weather. These problems are the result of urban runoff and numerous sewage treatment plants discharging to tributary streams, especially Deer and Chisholm Creeks. However, completion of tertiary sewage treatment plants presently under construction and planned in the area, waters impounded on Cottonwood Creek will be suitable for municipal and industrial uses with appropriate treatment

The Salt Fork of the Arkansas River draining northern portions of the region has very poor quality water. The water is extremely hard and very high in pH, often exceeding the Oklahoma water quality standards, however dissolved oxygen remains near saturation levels. The stream is moderately turbid, and chromium, lead and mercury levels occasionally violate standards.

The Deep Fork River in Logan and Lincoln Counties of this planning region contains turbid, hard water, although dissolved oxygen remains near saturation levels and no toxic metals have been noted recently.

The Chikaskia River, a tributary of the Salt Fork, has good water quality with low nutrient and mineral levels and dissolved oxygen remaining near saturation levels throughout the year The river has hard water, moderate turbidity and the pH sometimes exceeds water quality standards.

The Arkansas River forms part of the eastern boundary of the North Central Planning Region. The river enters the state in Kay County and has poor water quality due to heavy nutrient loading and high mineralization. The nutrient quality improves, but due to elevated chloride concentrations, the mineral quality degrades significantly below its confluence with the Salt Fork. The stream has hard water and turbidity is moderately high in the headwaters-to-Ralston segment, but becomes much less turbid downstream. The river is slightly alkaline with high pH, but dissolved oxygen remains near saturation levels. Iron and manganese frequently exceed recommended limits, and of the toxic metals, chromium sometimes exceeds limits in the upper reaches.

STREAM WATER DEVELOPMENT

The North Central Planning Region has experienced limited surface water development because of poor stream water quality. There are two existing major reservoirs constructed by the Corps of Engineers and three major municipal lakes in the region.

Major Reservoirs

Kaw Reservoir, located on the main stem of the Arkansas River, was completed in May 1976. Authorized purposes of the project include flood control, water supply, water quality, recreation and fish and wildlife. Provisions for possible future development of hydroelectric power have been included in Kaw Dam, however installation of power facilities has not yet been authorized. Flood control storage is over 860,000 acre-feet, with a water supply and water quality storage capacity of 203,000 acre-feet. Water supply yield, including water quality storage, is 230,700 acre-feet per year. Oklahoma Gas and Electric Company is allocated approximately 40,000 acre-feet of water for cooling purposes at the company's generating plant downstream. Kaw City and the Kaw Reservoir Authority consisting of the member cities of Enid, Stillwater, Perkins, Yale, Perry, Tonkawa, Ponca City, Blackwell, Braman, Shidler, Morrison and Billings also have allocations of storage in the reservoir. The Kaw Reservoir Authority is seeking funding to finance a regional distribution system from Kaw to the member cities. If such efforts are successful, the regional system will be the largest such system in the state.

Water quality of the reservoir is fair and considered suitable for most beneficial purposes.

Keystone Lake, also located on the main stem of the Arkansas River, was completed in 1965, and authorized for flood control, water supply, hydroelectric power, navigation and fish and wildlife. The project contains 1,218,500 acre-feet of flood control storage, along with 330,500 acre-feet of power storage. Water supply storage of 20,000 acre-feet provides a yield of 22,400 acre-feet annually. Two 35,000-kilowatt power generation units at the lake produce an average of 228 million kilowatt hours of energy each year. Public Service Company is allocated storage and utilizes water for cooling purposes at their plant in Tulsa.

Water quality of Keystone is poor due to the confluence of the Salt Fork and the Arkansas River upstream and the entrance of the Cimarron River at the southwest corner of the lake. Although poor quality restricts the use of water for most beneficial uses, the lake is an important recreational facility for area residents and tourists.

Major Municipal Lakes

Lake Carl Blackwell, on Stillwater Creek in Payne County, was built by the U.S. Department of Agriculture, and is owned and operated by Oklahoma State University. The university uses water and sells water to the City of Stillwater for municipal and industrial purposes. The lake contains 55,000 acre-feet of water supply storage with a yield of 7,000 acre-feet per year.

In addition to providing water supply to Stillwater, the lake plays a significant role in the research and educational mission of the university. Since its completion in 1937, Lake Carl Blackwell has also offered abundant recreational opportunities to residents of the area.

Lake McMurtry is located on North Stillwater Creek, north of Lake Carl Blackwell. Owned by the City of Stillwater, the lake has 5,000 acre-feet of flood control storage as well as 13,500 acre-feet of water supply storage, with a dependable yield of 3,000 acre-feet annually. McMurtry also provides recreational opportunities complementing those of Lake Carl Blackwell.

Lake Ponca was completed in 1935 on Big and Little Turkey Creeks approximately three miles north of Ponca City. The city maintains a park

FIGURE 81 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Lake Carl Blackwell	Stillwater Creek	WS, R	0	55,000	7,000
Kaw Lake	Arkansas River	WS, FC, WQ, R, FW	866,000	203,000[1]	230,700[1]
Keystone Lake	Arkansas River	WS, FC, P, FW	1,218,500	20,000	22,400
Lake McMurtry	North Stillwater Creek	WS, FC, R	5,000	13,500	3,000
Lake Ponca	Big and Little Turkey Creeks	WS, R	0	15,300	9,000
Sooner Lake[2]	Greasy Creek	P, FC, R	47,500	149,000[2]	3,600[2]
TOTAL			2,137,000	455,800	275,700
		POTENTIAL			
				CONSERVATION STORAGE	
Hennessey	Turkey Creek	WS, R, FW, I	0	173,000	18,800
Hunnewell	Chikaskia River	WS, FC, R, I	112,000	473,400	54,700
Lela	Black Bear Creek	WS, FC, R	84,000	199,200	48,400
Otoe	Red Rock Creek	WS, FC, R, I	142,000	403,300	46,000
Seward	Cottonwood Creek	WS, FC, R	51,000	128,200	21,700
Sheridan	Skeleton Creek	WS, FC, R, I	91,000	195,500	24,000
TOTAL			480,000	1,572,600	213,600
TOTAL YIELD					489,300

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

[1]Includes water quality control storage of 31,800 acre-feet which yields 43,680 acre-feet per year.

[2]Provides existing and ultimate cooling water requirements for Oklahoma Gas and Electric Company's electric generation station. The conservation storage includes 128,000 acre-feet of inactive storage utilized as a heat sink for cooling purposes. The 3,600 acre-feet per year yield listed is developed locally from the Greasy Creek Drainage area. An additional yield of approximately 40,000 acre-feet per year is developed from releases of storage provided in Kaw Lake.

with recreational facilities around the lake.

Dependable yield from the lake is 9,000 acre-feet of water annually. The City of Ponca mixes this lake water with ground water to supply the city's needs.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered the construction of numerous flood control structures for watershed protection and flood prevention throughout the North Central Planning Region. Of the 38 small watersheds in the region, 16 are complete or under construction, 13 are planned and nine have potential for development.

With increased emphasis on multipurpose projects, seven such projects were developed in this planning region. In addition to widespread recreational use, many local sponsors such as Perry, Stroud, Stillwater, Meeker, Sparks, Lucien and Langston have added water storage for municipal purposes. Similar structures combining the purposes of recreation and municipal water supply are planned for the Cities of Chandler, Wellston, Prague, Pawnee, Morrison and Glencoe.

Authorized Development

There are no authorized projects in the North Central Planning Region.

Potential Development

Because of constraints imposed by poor water quality of the major rivers in the North Central Planning Region, potential for additional stream water development is generally limited to sites located on tributary streams. An exception is the Hunnewell site located on the Chikaskia River, which would offer good quality water. The potential Seward site on Cottonwood Creek is presently undergoing feasibility-level investigations to determine its suitability as a future water supply source for the City of Guthrie. In addition, those sites listed in Figure 81 offer the greatest potential for development.

STREAM WATER RIGHTS

As of February 20, 1979 there had been issued a total of 321 vested stream water rights and permits for the appropriation of 392,298 acre-feet of water per year from rivers, streams and lakes in the region. The tabulation by county and use is shown in Figure 82 .

Ground Water

The Vamoosa Formation, Garber-Wellington Formation and alluvium and terrace deposits are the three major ground water basins in the North Central Planning Region. See Figure 28 . Ground water is the source of water for most of the area's rural homes, many municipalities and extensive irrigated agriculture. See Figure 29 for estimated total water in storage and amounts recoverable from ground water basins.

Vamoosa Formation (Pennsylvanian) outcrops in Pawnee County and in eastern Payne and Lincoln Counties. It ranges in thickness from 300 to 400 feet and consists of interbedded sandstone, shale and conglomerate, with the amount of sandstone decreasing northward. The rock types in the Vamoosa differ in color and grain sizes, varying from fine to extremely coarse in clastic rocks. The sandstone of the aquifer yields about 100 gpm. Chemical quality of the water ranges widely, but generally has a high concentration of sodium bicarbonate.

Garber-Wellington Formation (Permian) consists of two rock units, the Garber Sandstone and the Wellington Formation, deposited under similar conditions and considered a single water-bearing zone. Both contain lenticular beds of red, fine-grained sandstone alternating with shale. The formation is approximately 300 feet thick near the Oklahoma-Logan County Line. In Logan County it is shaly and has low permeability, with wells yielding 10 gpm or less near Guthrie. Generally, the water is suitable for most purposes, but in some areas it is hard and high in sulfate, chloride, flouride and nitrate

FIGURE 82 STREAM WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Garfield	3	160	2	251	36	3,597	—	—	1	80	—	—	42	4,088
Grant	—	—	—	—	9	1,460	—	—	—	—	1	15	10	1,475
Kay	10	107,282	3	94,000	31	5,867	—	—	1	90	1	1	46	207,240
Kingfisher	—	—	1	60	26	9,102	—	—	1	76	1	145	29	9,383
Lincoln	8	7,057	—	—	23	4,819	—	—	1	55	2	45	34	11,976
Logan	6	39,109	6	1,991	48	8,045	—	—	1	136	2	45	63	49,326
Noble	5	2,940	—	—	22	2,264	—	—	1	30	—	—	28	5,234
Pawnee	9	9,521	2	6,828	11	1,972	1	5	4	620	—	—	27	18,944
Payne	5	62,497	2	3,752	32	5,739	—	—	1	100	2	12,544	42	84,632
Total	46	228,566	16	106,880	238	42,865	1	5	11	1,187	9	12,795	321	392,298

FIGURE 83 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Garfield	44	21,276	3	592	13	2,038	—	—	2	124	—	—	62	24,000
Grant	12	26,205	—	—	48	13,254	—	—	—	—	—	—	60	39,459
Kay	9	47,808	5	8,197	29	8,154	2	1,648	1	74	—	—	46	65,881
Kingfisher	20	6,661	5	17,253	162	44,186	2	2,300	—	—	—	—	189	70,400
Lincoln	10	3,987	1	161	9	1,297	1	1,175	2	151	—	—	23	6,771
Logan	5	1,417	1	1,150	21	6,056	1	2,000	3	917	—	—	31	11,540
Noble	6	587	—	—	10	4,016	1	188	—	—	—	—	17	4,791
Pawnee	4	1,800	—	—	4	1,360	1	211	1	298	—	—	10	3,669
Payne	10	1,289	4	5,952	22	10,354	3	658	3	202	—	—	42	18,455
Total	120	111,030	19	33,305	318	90,715	11	8,180	12	1,766		0	480	244,996

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

concentrations. Dissolved solids range from 100 to 1,000 mg/L.

Alluvium and terrace deposits (Quaternary) are found in all of the region's nine counties, mainly along the Salt Fork of the Arkansas River across Grant and Kay Counties. Minor extensions reach in to Pawnee County and along the Cimarron River across Kingfisher County into Logan County. The deposits were stream-laid in an irregular pattern and consist of unconsolidated clay, silt, sand and gravel which interfinger.

The alluvium and terrace deposits along the Salt Fork reach a maximum thickness of about 60 feet, while similar deposits along the Cimarron attain a thickness of 120 feet. Maximum saturated thickness for the Salt Fork and the Cimarron deposits are 35 and 50 feet, respectively. Well yields from the alluvium of the Salt Fork average 400 to 500 gpm, while yields from the terrace are approximately 100 to 200 gpm. Well yields along the Cimarron range from 1,000 gpm to less than 50 gpm, averaging 100 to 300 gpm.

The water of the Cimarron alluvium is of poor quality due to high chloride and sulfate concentrations introduced upstream. Water quality of the Cimarron terrace deposits is generally suitable for most purposes, except in some areas where salt water encroachment has made the water unfit for domestic use. The water is hard and is of a calcium magnesium bicarbonate type. Dissolved solids average 350 mg/L. Water from the alluvium of the Salt Fork is poor, due to high sulfate and chloride concentrations, while that of the terrace deposits is suitable for most purposes and chemically similar to ground water of the Cimarron terrace.

GROUND WATER DEVELOPMENT

Only a small part of the water stored in the Garber-Wellington Formation is presently being utilized. The most productive portion of the basin is south of the Cimarron River to the Oklahoma County line. Although a few small towns and rural homes north of the Cimarron utilize water from the aquifer, low yields and the threat of salt water intrusion limit development in the lower portion of the basin. Potential exists for greater development, but the number of wells, their spacing and pumping rates will require management in order to prevent saline intrusion which could significantly reduce the supplies of fresh ground water.

Terrace deposits along the Cimarron River provide municipal and industrial water to the Cities of Enid and Hennessey, as well as ground water for irrigation. Some small communities and rural water districts utilize water from wells in the terrace of the Salt Fork of the Arkansas River. The terrace and alluvium deposits in the North Central Planning Region are only slightly developed and have the potential for the development of large capacity wells.

The Vamoosa Formation is the most important aquifer in this planning region and has the greatest potential for further development. As well as the Cities of Cushing, Stroud and Prague, many smaller towns and industries obtain water from the aquifer. The most favorable area for development appears to be the southeast corner of Payne County and Northeast Lincoln County, due to the water being of questionable quality in other areas.

GROUND WATER RIGHTS

As of July 1979, there was a total of 480 ground water permits issued, allocating fresh ground water for municipal, irrigation or industrial use. See Figure 83 .

PRESENT WATER USE AND FUTURE REQUIREMENTS

The population of the North Central Planning Region was estimated at 262,800 in 1977, and is projected to increase to 412,100 by the year 2040. Present annual water use is estimated at 126,400 acre-feet and is projected to increase by 2040 to 659,900 acre-feet. Municipal and industrial uses are currently the largest water use categories, however, irrigation is anticipated to consume over half the total water requirements by the year 2040.

Municipal water uses, which include rural domestic water needs, are presently estimated to be 45,600 acre-feet per year, but an increasing population is expected to push municipal water requirements to 101,600 acre-feet anually by 2040. The majority of this increase is due to expected growth of the Cities of Enid, Stillwater and Ponca City.

Rural water needs are currently being met by 53 rural water districts serving almost 35,000 customers. Future rural growth will require expansion of existing systems and creation of new ones to satisfy the water needs of the numerous small towns and rural areas in the region.

Industrial water use in the North Central Planning Region is presently 47,600 acre-feet per year. Oil and gas refineries, along with iron and steel manufacturers and machinery production companies, are the largest industrial water users. Industrial water needs are projected to rise to 59,300 acre-feet annually by 2040.

Water for the generation of power presently amounts to 4,600 acre-feet annually in this planning region. Oklahoma Gas and Electric Company operates one small generating plant at Enid with a net generating capacity of 48 megawatts, and has a second under construction near Red Rock, Oklahoma. This plant will initially consist of two 510-megawatt generating units, and is designed to ultimately accommodate additional units with a potential capactiy of 4,500 megawatts, Water from Kaw Lake will be released and diverted downstream into Sooner Lake to provide cooling water for the fossil fueled power plant.

Irrigation water use is presently 28,600 acre-feet per year and is projected to rise to 336,900 acre-feet annually by 2040. The Oklahoma State University 1977 Irrigation Survey showed 17,552 irrigated acres in the region, with almost 80 percent of this being in Kingfisher County, where wheat and pasture grasses are primary irrigated crops. By 2040, the 9-county region is projected to contain 224,600 irrigated acres.

FIGURE 84 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	45.6	58.1	67.4	77.3	85.5	93.9	101.6
Industrial	47.6	48.9	49.4	51.5	53.0	54.1	59.3
Power	4.6	42.9	66.7	90.6	114.4	138.3	162.1
Irrigation	28.6	82.8	133.5	179.4	238.2	282.3	336.9
Total	126.4	232.7	317.0	398.8	491.1	568.6	659.9

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Much of the water in the North Central Planning Region is of inferior quality due to high natural chloride concentrations in upper reaches of its streams. Poor water quality has restricted stream water development and forced reliance on ground water resources. Although Kaw Reservoir in Kay County was completed in 1976, little of its total yield is presently utilized.

Existing water resources — ground water, SCS lakes and Kaw Reservoir — can supply 242,300 acre-feet annually and potential local sources could provide an additional 319,400 acre-feet per year. However, as Figure 85 indicated, even at ultimate proposed development, by the year 2040 this region would still face an annual deficit of 98,200 acre-feet which will have to be met by sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a plan to meet a portion of the region's future water needs which includes the construction of five new reservoirs to provide north central Oklahoma with an additional 210,900 acre-feet of water per year. See Figure 86 . These are: Hennessey, Hunnewell, Lela, Otoe and Seward. Seward would annually provide Logan County with 14,500 acre-feet of water for municipal and industrial use. Hennessey would yield 18,400 acre-feet per year to Kingfisher County, primarily for irrigation. Hunnewell, on the Chickaskia River, would be supplemented with an average 39,600 acre-feet of water per year received from Kaw Reservoir via a diversion canal, increasing its total annual yield to 72,600 acre-feet. Grant County would receive all of this amount, most of which would be used for irrigation purposes Lela Reservoir would provide Payne and Pawnee Counties with 38,200 acre-feet per year for municipal and industrial purposes. Finally, the yield of Otoe Reservoir would be supplemented from the Arkansas River by a diversion channel located above the Salt Fork-main stem confluence in order to ensure good quality water. Otoe would yield 64,200 acre-feet per year primarily for irrigation purposes.

Additional ground water and SCS structures could provide 108,500 acre-feet per year, primarily for irrigation purposes Ground water is projected as a major source of supply only in Lincoln County.

Based upon 1.5 acre-feet of water per acre, 182,000 acres are projected to be irrigated by the year 2040. Figure 85 shows the nine counties in the region, their proposed supplies and projected demands in 2040. The overall regional deficit is a result of the lack of adequate water sources in the Garfield County area.

In addition to new source development, pertinent irrigation and municipal and industrial distribution facilities are proposed in the Regional Plan of Development. Also included is a water distribution system from Kaw Reservoir proposed by the Kaw Reservoir Authority to serve several

FIGURE 85 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Garfield	Grant	Kay	Kingfisher	Lincoln	Logan	Noble	Pawnee	Payne	Total
				Municipal and Industrial Component[1]						
Ground Water & SCS & Municipal Lakes[2]	11.2	1.5	9.0	3.6	12.1	0.9	0.4	0.1	11.0	49.8
Kaw	—	—	139.8	—	—	—	40.0	—	—	179.8
Hennessey	—	—	—	1.9	—	—	—	—	—	1.9
Hunnewell	—	1.5	—	—	—	—	—	—	—	1.5
Lela	—	—	—	—	—	—	—	6.1	32.1	38.2
Otoe	—	—	—	—	—	—	3.0	—	—	3.0
Seward	—	—	—	—	—	14.5	—	—	—	14.5
M & I Supply	11.2	3.0	148.8	5.5	12.1	15.4	43.4	6.2	43.1	288.7
					Irrigation Component					
Ground Water & SCS Lakes	15.6	16.5	14.7	15.3	17.4	13.5	13.2	4.5	13.5	124.2
Hennessey	—	—	—	16.5	—	—	—	—	—	16.5
Hunnewell	—	71.1	—	—	—	—	—	—	—	7.1
Otoe	—	—	54.3	—	—	—	6.9	—	—	61.2
Irrigation Supply	15.6	87.6	69.0	31.8	17.4	13.5	20.1	4.5	13.5	273.0
TOTAL LOCAL SUPPLY	26.8	90.6	217.8	37.3	29.5	28.9	63.5	20.7	56.6	561.7
2040 DEMAND	125.0	90.6	217.8	37.3	29.5	28.9	63.5	10.7	56.6	659.9
NET DEFICIT	98.2	—	—	—	—	—	—	—	—	98.2

[1]Includes cooling water (power) demands.

FIGURE 86 PROPOSED PLAN OF DEVELOPMENT

local communities with municipal and industrial water.

Figure 87 presents the total construction cost of all proposed facilities, estimated at $840 million, with an average annual equivalent cost of $66 million. The construction cost of new SCS lakes is estimated to be $32.4 million, with an average annual equivalent cost of $1.2 million. This cost includes local water supply storage for irrigation purposes, but excludes distribution facilities. New ground water development is estimated to cost $1.6 million, with $300,000 of average annual equivalent costs. The $805 million construction cost for major reservoirs includes five dams and reservoirs, appropriate distribution facilities, mitigation/compensation costs and the Kaw Reservoir Authority water supply system. Also included are the conveyance channels from Kaw to Hunnewell and from the Arkansas River to Otoe. Annual OMR&E cost is $4.7 million, with average annual equivalent cost of $64.7 million. Each proposed reservoir would require additonal studies to determine its feasibility according to federal criteria and the amount of state or local contributions which could be necessary

Cost estimates for the Kaw Reservoir water supply system are just over $80 million, which included cost of distribution and storage. The costs for this regional water supply system could be considerably lower than those for the independent facilities proposed by some local cities and towns, and such development would be more consistent with the Regional Plan of Development proposed herein.

FIGURE 87 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes	$ 32,375	$ 15	$ 1,200
Ground Water Development	1,600	200	300
Kaw Reservoir			
M & I Distribution	$ 80,000	$ 500	$ 5,310
Subtotal	$ 80,000	$ 500	$ 5,310
Hennessey			
Dam & Reservoir	$ 42,700	$ 40	$ 3,200
Irrigation Distribution	23,650	270	1,860
M & I Distribution	3,940	50	300
Mitigation/Compensation	3,325	25	250
Subtotal	$ 73,615	$ 385	$ 5,610
Hunnewell			
Dam & Reservoir	$ 81,600	$ 50	$ 5,700
Conveyance from Kaw	27,990	380	1,700
Irrigation Distribution	101,910	1,270	7,970
M & I Distribution	7,300	50	510
Mitigation/Compensation	20,700	25	1,400
Subtotal	$239,500	$1,725	$17,280
Lela			
Dam & Reservoir	$ 61,560	$ 40	$ 4,300
M & I Distribution	43,950	670	3,670
Mitigation/Compensation	8,500	25	5,880
Subtotal	$114,010	$ 735	$13,850
Otoe			
Dam & Reservoir	$108,000	$ 50	$ 8,000
Conveyance from Arkansas River	15,140	240	1,000
Irrigation Distribution	87,720	710	6,860
M & I Distribution	22,440	160	1,760
Mitigation/Compensation	16,200	25	1,100
Subtotal	$249,500	$1,185	$18,720
Seward[4]			
Dam & Reservoir	$ 38,900	$ 40	$ 3,100
M & I Distribution	9,580	140	840
Subtotal	$ 48,480	$ 180	$ 3,940
TOTAL	$839,080	$4,925	$66,210

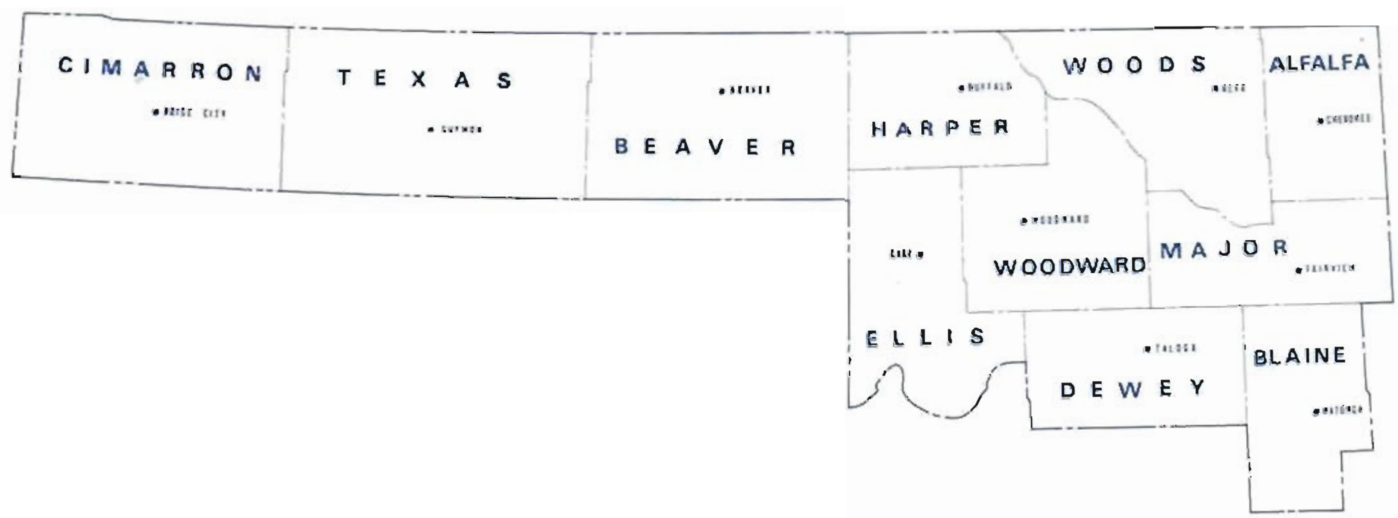
[1]Based on January 1978 prices.

[2]Energy costs computed at a 30-mil power rate.

[3]Includes interest and amortization as well as annual OMR&E expenses.

[4]Preliminary studies indicate no mitigation/compensation necessary for Seward, however, final determination is not completed.

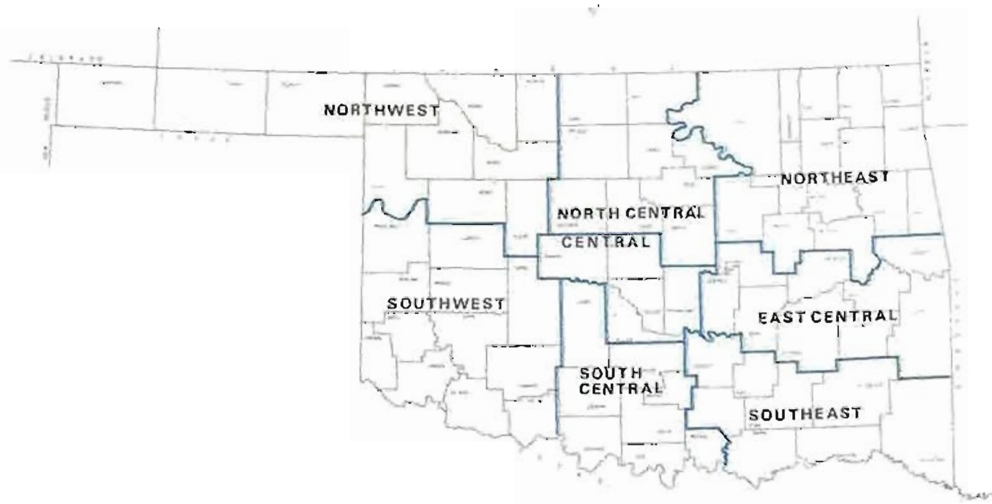
NORTHWEST PLANNING REGION



The Northwest Planning Region, composed of Alfalfa, Beaver, Blaine, Cimarron, Dewey, Ellis, Harper, Major, Texas, Woods and Woodward Counties, covers 14,339 square miles. Drought has become a way of life in these counties which register the state's lowest rainfall measurements. The three Panhandle counties—Cimarron, Texas and Beaver—are flat, while the remainder of the region is rough and marked by high sand hills and deep erosion.

The region supports the most extensive agricultural activities in the state, its bountiful feed and grain crops and fed cattle industry thriving on lands irrigated from the giant Ogallala aquifer and terrace and alluvium deposits. The Ogallala and other ground water deposits provide good quality water for irrigation. Future water shortages, along with escalated pumping and energy costs, could cause the pumping of ground water for the irrigation of marginally profitable crops to become economically infeasible. Unless a dependable new water supply is developed, farmers will have to revert to dryland farming, a measure which would substantially reduce crop yields and stifle agricultural production.

The 1977 population of the 11-county region was estimated at 102,000, a 5.5 percent increase over the 1970 figure of 96,719. During that same period, per capita personal income rose from $3,861 to $6,226, and average annual covered employment increased from 11,063 to 21,282. The slow population growth reflects, at least in part, the region's harsh climate and geographic conditions.



However, the area's per capita income ranks highest among those of the state's eight planning regions. The region's unemployment rate historically has been the lowest in the state, averaging just above two percent between 1974 and 1978. This low rate probably is partially attributable to involvement in agricultural activities from which heavy capital investment and tradition make withdrawal difficult, even during economically troubled times. Major industries are agriculture, wholesale and retail trade and personal services. The largest cities in the Northwest Planning Region are Woodward, Guymon and Alva.

The widespread development and prosperity of the region are credited to irrigation with water from the Ogallala aquifer, a vast underground basin of water underlying nine of the 11 counties. However, minimal rainfall and runoff contribute little recharge to the Ogallala, causing it to be pumped at a much faster rate than it can refill and resulting in ground water mining. Alternative water supplies must be made available if the region is to continue its current economic progress.

The climate ranges from semi-arid in the Panhandle to subhumid in the remainder of the region. As shown in Figure 8, the average annual precipitation varies from 16 inches in the Panhandle to 28 inches in eastern Major and Blaine Counties, with most of it occurring in the spring, and May being the wettest month of the year. Thunderstorms dominate the rainfall pattern during the growing season, often producing high winds and damaging hailstorms. Although tornados seldom occur in the Panhandle, they cause frequent damage to the remainder of the area, particularly in Woodward, Dewey and Blaine Counties. The region receives almost 18 inches of snowfall in an average year.

Average annual lake evaporation ranges from 56 inches in the west to 64 inches in the southwest corner, and evaporation losses greatly in excess of precipitation create critical and persistent water problems. High winds and hot temperatures cause this exceptionally high evaporation rate, and since evaporation is a major consideration in reservoir design, additional water storage must be allowed in order to maintain dependable water supply yields.

Mean annual temperatures vary from 57° in the Panhandle to 61°F in the eastern part of the region, as shown in Figure 7. The length of the growing season averages about 170 days in the west to 250 days in the southeastern counties. The northwest region has been scourged by long and disastrous droughts since the Dust Bowl days of the 1930's. The worst years of the decade were 1933, 1934 and 1936, while in stark contrast, the beginning and end of the period were relatively humid. The 1950's were marked by another period of severe drought, even longer and more widespread than that of the 1930's. Flooding is uncommon in the region, but when it does occur, four large flood control reservoirs built by the Corps of Engineers (Optima, Canton, Fort Supply and Great Salt Plains) and a few smaller SCS structures should prevent widespread damage. As a result of flooding, agriculture suffers the greatest damage, while urban property registers less severe losses.

WATER RESOURCES

Stream Water

Major streams in the Northwest Planning Region are the Salt Fork of the Arkansas River; the Cimarron River, which enters the state from eastern New Mexico; the Canadian, which enters from Texas; and the North Canadian (Beaver River), which enters from the west side of the Oklahoma Panhandle. Available stream water is of insufficient quantity and inadequate quality to provide significant amounts of water to the area.

Average annual runoff ranges from 0.2 inches in the western Panhandle to two inches in the eastern fringe of this region. Total average annual runoff originating in this region is estimated at 820,000 acre-feet. A summary of streamflow records at U.S. Geological Survey gaging stations in the region is presented in Appendix B, Figure 2.

The beneficial use of all the major streams in the Northwest Planning Region is restricted by poor water quality, causing most local water to be unacceptable under public health standards for municipal or domestic use. Streams contain excessive amounts of salt and other dissolved minerals brought into solution as the water moves through the basin. Water quality analyses data for selected U.S. Geological Survey monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5

The Cimarron River is of fair quality on entry from New Mexico in Cimarron County and re-entry further east. Quality of the river on its third entry at the Harper-Woods County line is degraded by salt sources in Kansas and local sources which often raise the river's salt content higher than that of sea water. A slight decrease in mineralization occurs downstream from Waynoka. Cimarron water is very hard with moderate to high turbidity, pH in excess of standards and some toxic metals problems, but dissolved oxygen remains at or near saturation levels throughout the year.

The Salt Fork of the Arkansas River passes through the Great Salt Plains and is highly mineralized and chemically unsuitable for most beneficial uses. The water of a number of northern tributaries of the Salt Fork is of good or fair quality and suitable for municipal and domestic use. Dissolved oxygen usually remains near saturation levels.

The North Canadian River has generally poor quality water in the Northwest Planning Region due to elevated levels of nitrogen and phosphorus in the upper portions and increased mineralization by sulfates and chlorides downstream, preventing its use for most municipal and domestic purposes. High sodium and dissolved mineral content in the water of the North Canadian downstream from Palo Duro Creek causes fair to poor quality for irrigation purposes, but tributaries in this reach that drain the Ogallala ground water formation exhibit water of good quality. Upstream from Palo Duro Creek water is of good quality and suitable for most uses.

The (South) Canadian River in this planning region has hard, highly mineralized water. Nutrient levels are high where the river enters Oklahoma from Texas, but improve in the river's flow through the region. Turbidity standards for warm water streams are occasionally violated and pH sometimes exceeds standards, but dissolved oxygen remains at or near saturation levels most of the year.

STREAM WATER DEVELOPMENT

Poor water quality and adverse climatological conditions have limited reservoir development in the region. Of the four major reservoirs, Canton, Fort Supply and Optima Lakes supply water for municipal and industrial uses, while Great Salt Plains Lake serves mainly as a flood control structure.

Major Reservoirs

Canton Lake on the North Canadian River was completed in May 1948. Authorized purposes of the project include flood control, water supply and irrigation. Irrigation storage in the lake has yet to be utilized for that purpose. By yearly contract Oklahoma City leases storage in Canton to supplement its supply, pending development of irrigation features. Water quality of the reservoir is rated poor, registering high in total dissolved solids, chlorides and sulfates.

Fort Supply Lake, located on Wolf Creek, was completed in 1942 for the purposes of providing 86,800 acre-feet for flood control and 13,900 acre-feet for conservation storage. Major water users from this storage are Western State Hospital and the City of Fort Supply. The water quality of the lake is acceptable except during periods of low flow.

In recent years, the Corps of Engineers has considered raising the dam at Fort Supply to provide additional water supply storage for the area. Contingent upon this modification, the Oklahoma Water Resources Board has appropriated 6,722 acre-feet to the City of Woodward for municipal use

The Great Salt Plains Lake was completed in 1941, authorized for flood control and other conservation purposes. Storage allocated for flood control is 240,000 acre-feet. There is no water supply storage authorized in the project. The quality of the lake's water is very poor, degraded by natural chloride emissions upstream from the lake.

The Great Salt Plains National Wildlife Refuge, a critical habitat for migrating whooping cranes, occupies 31,174 acres of the project lands.

Optima Reservoir, among the earliest authorized for construction (1936), was begun in 1966 and final impoundment occurred in September 1978. Project purposes include flood control, water supply, recreation, and fish and wildlife propagation, with a dependable water supply yield of 5,400 acre-feet per year. Water quality tests show the water to be relatively hard with low chloride content, making it suitable for most municipal and industrial uses.

This good source of quality water is in high demand by towns in the Panhandle. Many more applications for water from Optima Reservoir have been made than the yield can satisfy, so the needs of each applicant will be examined closely to assure the best possible use of water available.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered construction of numerous flood control structures on 31 watersheds in the Northwest Planning Region for the purpose of watershed protection and flood prevention. Five watersheds are complete or under construction, 14 are planned and 12 have potential for development.

As secondary benefits, Laverne and other towns adjacent to these watershed structures use them for recreational purposes. For locations of SCS watersheds, see Figure 26 .

Authorized Development

There are no other authorized projects in the Northwest Planning Region.

Potential Development

The potential for additional stream water development in the Northwest Planning Region is restricted due to water quality considerations and availability of stream water. Minimal amounts of additional good quality stream water are available because of existing stream water rights and uses. Reservoir sites that have been investigated and show potential for future development are listed in Figure 88 .

STREAM WATER RIGHTS

As of Feburary 20, 1979, there had been issued 172 vested stream water rights and permits for the appropriation of 55,164 acre-feet of water per year from rivers, streams and lakes in the Northwest Planning Region. The totals by county and by use are shown in Figure 89 .

FIGURE 88 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.☐	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Canton Lake	North Canadian River	WS, FC, I	267,800	107,000[1]	13,440[1]
Fort Supply Lake	Wolf Creek	WS, FC, R	86,800	400	220
Great Salt Plains Lake	Salt Fork of Arkansas River	FC, R	240,000	0[2]	0[2]
Optima Lake	North Canadian River	WS, FC, R, FW	71,800	76,200	5,400
TOTAL			666,400	183,600	19,060
		POTENTIAL			
				CONSERVATION STORAGE	
Alva	Salt Fork of Arkansas River	WS, FC, R, FW, I	110,700	455,000	42,900
Boise City	Cimarron River	WS, FC, R, FW, I	15,500	450,000	0[3]
Cestos	Kizer Creek	WS, R, FW, I	0	80,400	0[3]
Englewood	Cimarron River	WS, FC, R, FW, I	595,000	252,000	71,200
Fort Supply Modification	Wolf Creek	WS, FC, R, FW	86,800	113,600	18,580[4]
Goodwell	North Canadian River	WS, FC, R, FW, I	62,000	400,000	4,000[3]
Hydro	Canadian River	WS, R, FW, FC	300,000	670,300	110,000
Slapout	North Canadian River	WS, FC, R, FW	137,000	249,000	18,800[3]
TOTAL			1,307,000	2,670,300	265,480
TOTAL YIELD					284,540

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

☐Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage than can be economically justified as a project purpose.

[1]This figure includes irrigation storage and yield of 69,000 acre-feet and 2,240 acre-feet per year, respectively.

[2]Waters of project are unsuitable for use because of high mineral content.

[3]These are terminal storage reservoirs and develop very little yield of their own.

[4]Additional yield with modification.

FIGURE 89 STREAM WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Alfalfa	—	—	—	—	21	6,208	—	—	—	—	4	1,037	25	7,245
Beaver	—	—	—	—	17	2,054	—	—	—	—	2	644	19	2,698
Blaine	1	240	—	—	12	2,144	—	—	—	—	2	356	15	2,740
Cimarron	—	—	—	—	16	7,076	—	—	—	—	2	652	18	7,728
Dewey	—	—	—	—	3	308	—	—	—	—	—	—	3	308
Ellis	—	—	—	—	16	1,692	—	—	1	1,225	—	—	17	2,917
Harper	—	—	—	—	27	15,344	—	—	—	—	1	356	28	15,700
Major	—	—	—	—	14	2,490	—	—	1	6	—	—	15	2,496
Texas	—	—	—	—	9	1,220	—	—	—	—	1	750	10	1,970
Woods	—	—	—	—	9	1,870	—	—	—	—	—	—	9	1,870
Woodward	1	6,722	—	—	10	1,838	—	—	1	892	1	40	13	9,492
Total	2	6,962	—	—	154	42,244	—	—	3	2,123	13	3,835	173	55,164

Ground Water

Major ground water basins in the Northwest Planning Region are the Rush Springs Sandstone, Ogallala Formation and alluvium and terrace deposits. See Figure 28 .

Ogallala Formation (Tertiary) consists of a heterogeneous mixture of sand, gravel, silt, clay, caliche and local beds cemented with calcium carbonate. The various rock types generally occur as lenses and poorly sorted beds of loosely cemented material. The maximum thickness of the Ogallala in the region is about 650 feet, but it thins along major drainageways and over bedrock highs.

The Ogallala is the principal source of ground water in the Oklahoma Panhandle. Well yields range from a few gallons per minute to more than 2,000 gpm, with those yielding less than 360 gpm usually not completed for irrigation wells.

Although most water from the aquifer contains more than 180 mg/L hardness, it is suitable for most purposes. Some wells tapping the lower zones of the Ogallala pump water containing dissolved solids in excess of 5,000 mg/L.

Alluvium and terrace deposits (Quaternary) consist of poorly sorted, unconsolidated, interfingering lentils of clay, sand and gravel. The most favorable deposits are along the North Canadian and Cimarron Rivers, where deposits are thick and permeable and yield as much as 700 gpm. Average yields for the alluvium and terrace are 100 to 300 gpm.

Even though the quality is often adversely affected by nearby streams, the water is generally suitable for most uses where the deposits directly overlie the Ogallala and are not in contact with the Permian redbeds.

Rush Springs Sandstone (Permian) in Blaine and Dewey Counties is a fine-grained sandstone, gradational northward into shale and thinning. Near Eagle City in Blaine County, the aquifer is approximately 247 feet thick; near Taloga in Dewey County it is about 186 feet thick.

The Rush Springs Sandstone provides water for domestic and municipal uses and a few irrigation wells in the area. Yeilds are generally less than 150 gpm, and the quality of the water ranges from good to poor due to concentrations of sulfate.

GROUND WATER DEVELOPMENT

The Ogallala Formation is the state's most important source of ground water, due to its areal extent, thickness, high permeability and most importantly, location in a water-short area of the state. It contains approximately 76,000,000 acre-feet of water in storage, and supplies most of the water requirements of the Panhandle. Water from the Ogallala is used to irrigate over 400,000 acres of agricultural land, as well as meeting the industrial, municipal and domestic needs of the region.

In 1960 there were approximately 400 ground water wells in the Panhandle; by 1965 the number had risen to 975; and in 1974 there were 2,067. High capacity wells are concentrated in areas south of Guymon, north of Goodwell and in the northwestern part of Texas County. In Cimarron County, closely spaced wells occur in the Boise City area and in the southwestern corner of the county near Felt. Such closely spaced wells pumped at high rates for significant periods of time create a cone of depression around the pumped wells, causing interference between wells and reducing their productivity. Declines in water levels up to 102 feet have been recorded over the past 25 years. See Figure 90 .

The Economic Development Administration is presently evaluating the economic effects of ground water depletion in the Ogallala in a 6-state area, including Oklahoma. The objectives of the EDA study are to determine potential development alternatives for the High Plains region and identify policies required to achieve promising development strategies.

The U.S. Geological Survey is also evaluating the Ogallala in an 8-state area, including Oklahoma. This study will develop the geohydrologic data base and computer models

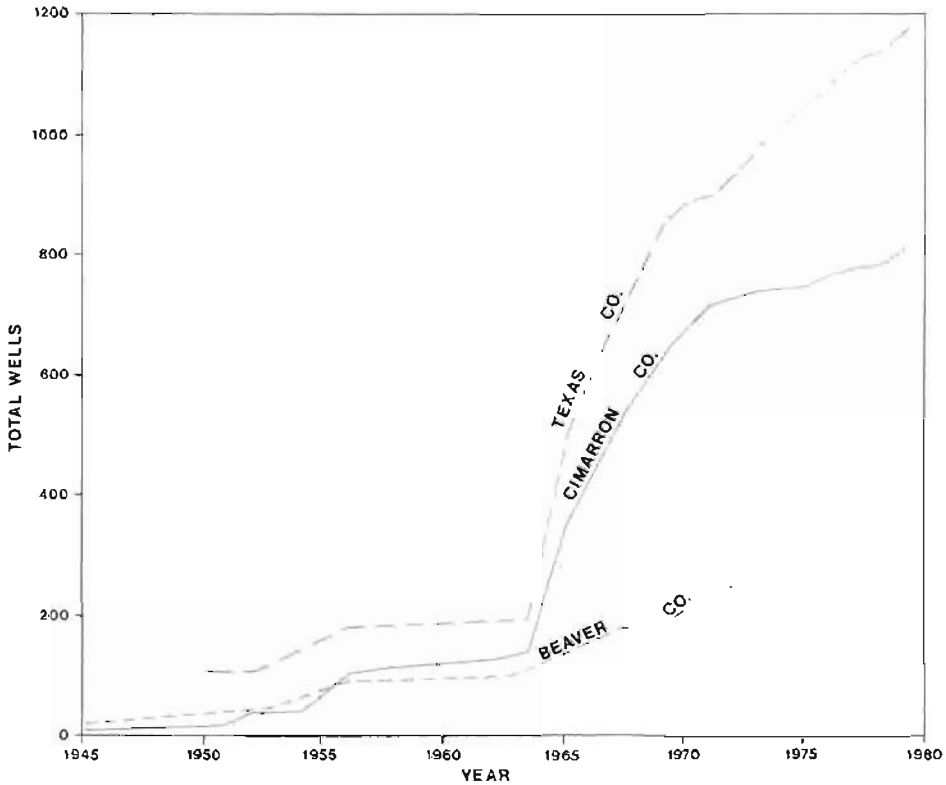


FIGURE 90 HIGH CAPACITY WELL DEVELOPMENT IN PANHANDLE COUNTIES (Domestic Wells Not Included)

of the ground water flow system needed to evaluate the response of the Ogallala Formation to ground water management alternatives.

The Rush Springs Sandstone provides municipal water supplies to Oakwood, Leedy and Putnam in Dewey County and to Canton in Blaine County.

GROUND WATER RIGHTS

As of July 1979, 2,955 ground water permits had been issued in the Northwest Planning Region. See Figure 91 . Prior rights have been established in eight counties in the Northwest Planning Region: Cimarron, Beaver, Texas, Woodward, Major, Harper, Dewey and Blaine.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Northwest Planning Region currently uses an estimated 885,200 acre-feet annually to meet its total water demands. Over 95 percent of this total is utilized for irrigation, enabling the region to support a thriving agricultural economy. Projections indicate that by the year 2040 the region will require 1,953,500 acre-feet per year to meet its water needs.

The 1977 estimated population of the region was 102,000 and the projected 2040 population is 135,200. Municipal water demand is anticipated to increase from the annual 16,800 acre-feet presently used to 27,600 acre-feet per year by 2040, with the Cities of Woodward and Guymon experiencing the largest increases.

Twenty-three rural water districts now serve over 10,000 customers in the Northwest Planning Region. The importance of these districts will increase in the future as rural populations grow and the areas further develop.

Present industrial water use in this region amounts to only 15,000 acre-feet per year, used largely by the oil and gas industry in processing and refining. Projected demand for industrial water indicates an increase of only nine percent to 17,800 acre-feet annually in 2040.

Cooling water used for power generation purposes presently ac-

FIGURE 91 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Alfalfa	16	9,637	1	20	61	17,767	5	2,140	3	323	1	100	87	29,987
Beaver	10	3,943	5	992	340	137,915	—	—	2	510	—	—	347	143,360
Blaine	11	9,212	1	150	61	17,198	—	—	—	—	2	400	75	26,960
Cimarron	5	3,743	1	1,610	566	445,358	—	—	—	—	—	—	572	450,711
Dewey	2	730	4	173	47	14,326	—	—	—	—	—	—	53	15,230
Ellis	3	1,409	—	—	142	61,484	—	—	—	—	1	80	146	62,973
Harper	5	1,299	4	432	111	42,946	—	—	1	350	—	—	121	45,027
Major	77	29,262	8	873	183	5,312	3	567	—	—	1	15	272	84,029
Texas	20	12,112	4	1,516	1,001	613,489	3	543	6	3,004	1	10	1035	630,674
Woods	7	37,149	—	—	60	16,408	—	—	—	—	—	—	67	53,557
Woodward	26	31,665	4	5,842	136	43,411	—	—	2	220	2	15	170	81,153
Total	182	140,161	32	11,608	2,708	1,463,625	11	3,250	14	4,407	8	620	2,955	1,623,661

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

FIGURE 92 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
Municipal	16.8	19.1	20.6	22.9	24.4	26.0	27.6
Industrial	15.0	15.2	15.3	15.9	16.3	16.3	17.8
Power	3.4	5.6	8.7	11.9	15.0	18.2	21.3
Irrigation	850.0	1077.6	1205.4	1377.8	1557.0	1724.4	1886.8
Total	885.2	1117.5	1250.0	1428.5	1612.7	1784.9	1953.5

counts for only 3,400 acre-feet per year in this region. Oklahoma Gas and Electric Company operates two small plants with a net capability of 15 megawatts, and Western Farmers Electric Cooperative maintains one plant in the area with a capacity of 313 megawatts. Future demand for power generation water is expected to rise to 21,300 acre-feet annually.

Since good quality stream water is very scarce, ground water resources have traditionally supplied most of the region's irrigation water needs. An estimated 850,000 acre-feet of water per year is currently used for the irrigation of 469,671 acres on 1,732 farms. It is projected that by the year 2040, the 11-county region will be irrigating 943,400 acres, requiring 1,886,800 acre-feet of water per year.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Due to low average annual rainfall and runoff, surface water development in the Northwest Planning Region has been very limited. Ground water presently provides most of the area's water needs The Ogallala aquifer, underlying eight of the 11 counties, is the most productive and most utilized of the ground water sources. However, in recent years local water tables have dropped and overdrafting threatens the continued usage of this important aquifer. It has become apparent that ground water resources cannot be relied upon as a long-term water supply.

Existing water sources in the region can supply 865,000 acre-feet per year from ground water, SCS and municipal lakes, and three major reservoirs. Potential development could provide an additional 141,400 acre-feet per year, however, as Figure 93 indicates, the region would still face a future deficit of 947,100 acre-feet per year which must be supplied from sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development which would utilize local water resources and include construction of two new reservoirs and pertinent municipal, industrial and irrigation distribution facilities. (See Figure 94 .) In addition, the plan would require increased usage of ground water (where supplies are available) and SCS and municipal lakes.

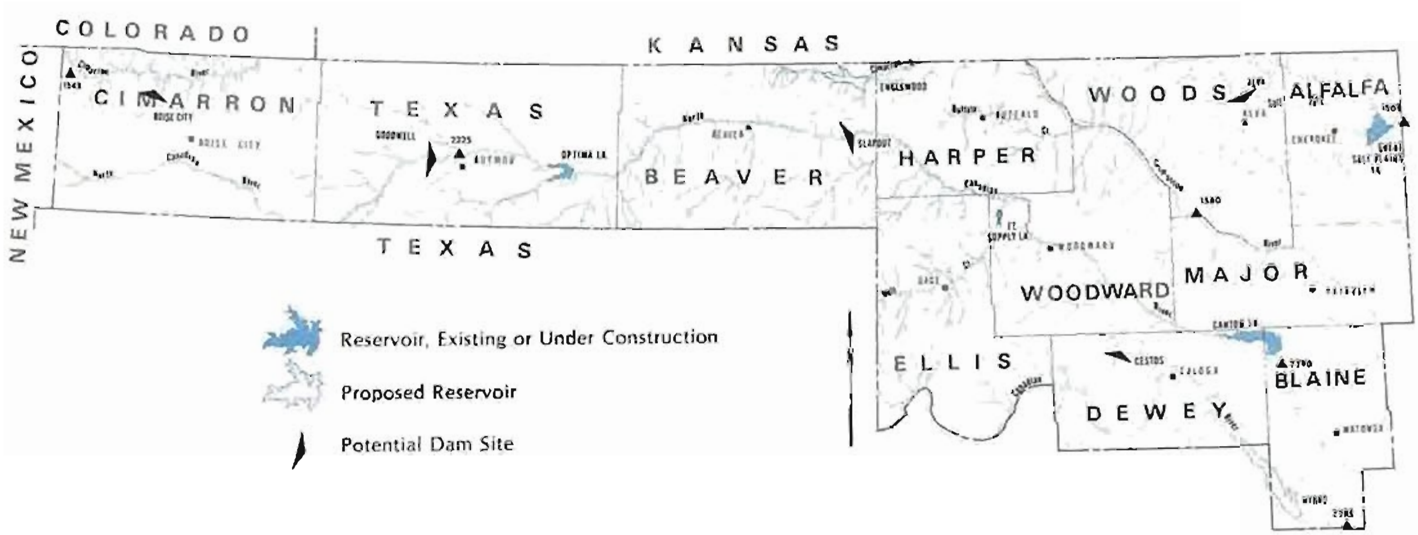
The two proposed reservoirs, Hydro and Englewood, would annually yield 91,700 acre-feet of water,

FIGURE 93 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Alfalfa	Beaver	Blaine	Cimarron	Dewey	Ellis	Harper	Major	Texas	Woods	Woodward	Total
Municipal and Industrial Component[1]												
Ground Water & SCS & Municipal Lakes	1.1	0.7	4.9	1.0	—	1.5	1.7	2.0	2.8	6.0	8.2	29.9
Canton	—	—	—	—	1.4	—	—	1.0	—	—	—	2.4
Fort Supply	—	—	—	—	—	—	—	—	—	—	6.5	6.5
Optima	—	0.8	—	—	—	—	—	—	4.6	—	—	5.4
Englewood	—	—	—	—	—	—	—	—	—	—	—	—
Hydro	—	—	1.5	—	—	—	—	—	—	—	—	1.5
M & I Supply	1.1	1.5	6.4	1.0	1.4	1.5	1.7	3.0	7.4	6.0	14.7	45.7
Irrigation Component												
Ground Water & SCS Lakes	12.0	86.4	12.8	186.4	—	9.8	12.8	15.2	492.0	3.8	16.0	847.2
Canton	—	—	7.0	—	2.0	—	—	2.0	—	—	—	11.0
Fort Supply	—	—	—	—	—	—	—	—	—	—	12.3	12.3
Englewood	—	—	—	—	—	—	31.2	—	—	—	—	31.2
Hydro	—	—	59.0	—	—	—	—	—	—	—	—	59.0
Irrigation Supply	12.0	86.4	78.8	186.4	2.0	9.8	44.0	17.2	492.0	3.8	28.3	960.7
TOTAL LOCAL SUPPLY	13.1	87.9	85.2	187.4	3.4	11.3	45.7	20.2	499.4	9.8	43.0	1,006.4
2040 DEMAND	62.1	201.7	85.2	529.4	10.0	63.7	45.7	28.2	822.9	45.3	59.3	1,953.5
NET DEFICIT	49.0	113.8	—	342.0	6.6	52.4	—	8.0	323.5	35.5	16.3	947.1

[1]Includes cooling water (power) demands.

FIGURE 94 PROPOSED PLAN OF DEVELOPMENT



Data—Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation
Mapping—Oklahoma Water Resources Board

primarily for irrigation purposes. Hydro Reservoir, on the Canadian River, would have a firm yield of 110,000 acre-feet annually and supply 60,500 acre-feet to Blaine County. Part of Hydro's remaining yield would be used in Caddo County in southwestern Oklahoma (44,200 acre-feet per year) and the rest (5,300 acre-feet per year) reserved for future demands. Englewood Reservoir, on the Cimarron River in Beaver County near the Kansas-Oklahoma line, would yield 31,200 acre-feet per year to serve the Harper County area.

Increased usage of ground water could yield 20,800 acre-feet per year, and development of new SCS structures could provide an additional 28,900 acre-feet of water per year. It is anticipated that these would be used solely for irrigation purposes.

A projected 480,000 acres would be irrigated in this region by the year 2040, based on two acre-feet of water per acre.

FIGURE 95 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes[3]	$ 20,700	$ 14	$ 1,470
Ground Water Development	3,800	230	490
Major Reservoirs			
Englewood			
Dam & Reservoir	$ 68,800	$ 50	$ 2,910
Irrigation Distribution	33,500	250	1,620
Mitigation/Compensation	2,190	25	170
Subtotal	$104,490	325	$ 4,700
Hydro			
Dam & Reservoir	$ 85,300	$ 60	$ 6,800
Irrigation Distribution	63,400	860	5,560
M & I Distribution	2,100	30	180
Mitigation/Compensation	9,040	25	625
Subtotal	$159,840	$ 975	$13,165
TOTAL	$288,830	$1,544	$19,825

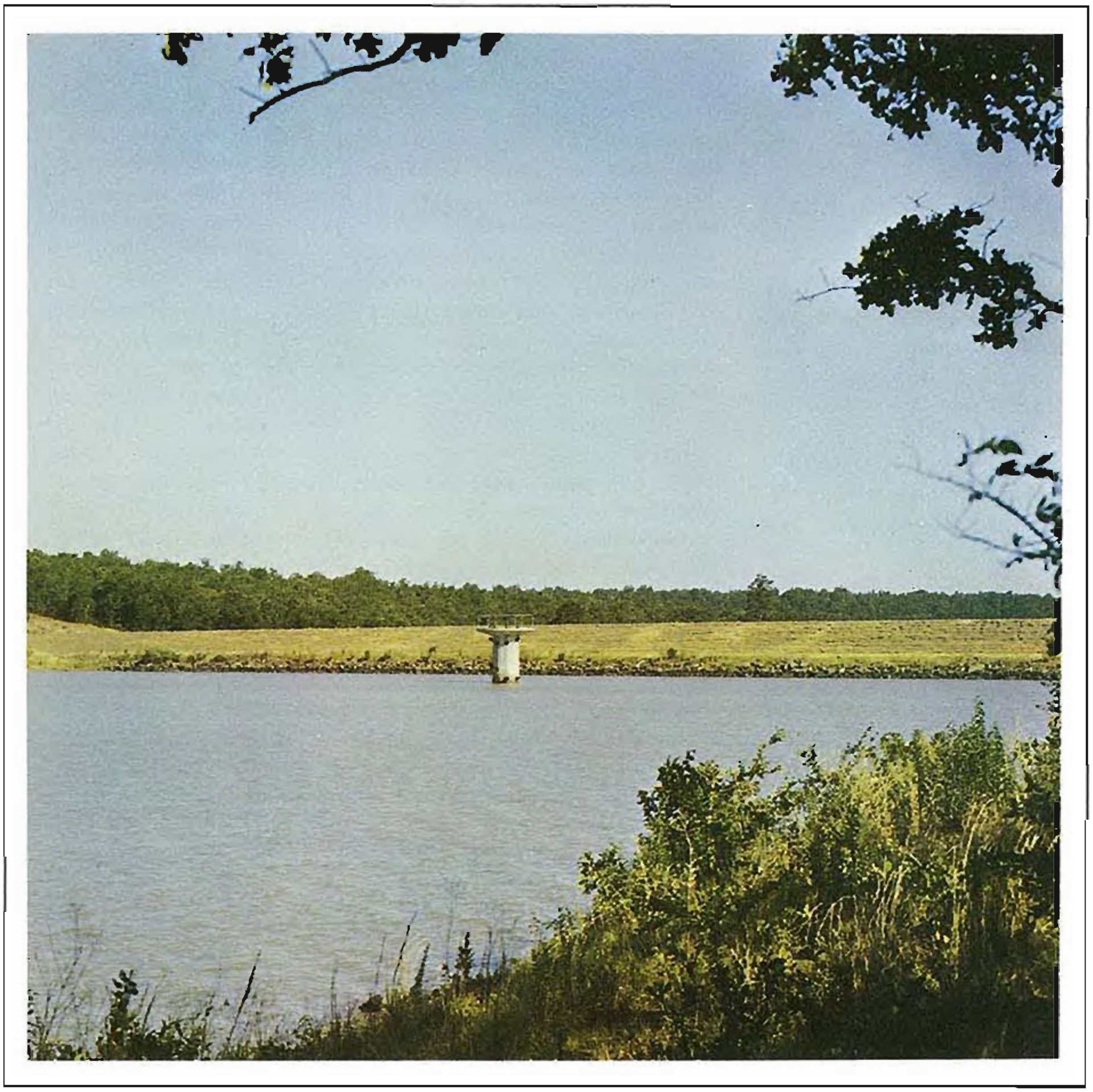
[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.

Figure 93 shows the 11 counties in the region, their planned water sources and projected 2040 demands. Nine of the 11 counties will face water shortages due to the lack of available local water supplies.

The total cost of the local proposed development is estimated to be $288.8 million, with an average annual equivalent cost of approximately $20 million. (See Figure 95 .) The cost for new ground water development would be $3.8 million, and new SCS lakes are estimated to cost $21 million. The SCS cost would include local water supply storage costs for irrigation water in a multipurpose project. Distribution costs from ground water and SCS lakes are not included, but should be addressed in future planning.

The construction cost for the proposed reservoirs would be $264.3 million, which includes the two dams and reservoirs, irrigation distribution facilities from both reservoirs, municipal and industrial distribution transmission lines from Hydro and mitigation/compensation costs. Annual OMR&E costs would be $1.3 million, with an average annual equivalent cost of $17.9 million. Additional studies would be required on each proposed reservoir to determine economic feasibility under federal guidelines, as well as the amount of state or local contribution that could be necessary.

CHAPTER VI
STATEWIDE WATER CONVEYANCE SYSTEM



INTRODUCTION

Most of the state's water resources are located in eastern Oklahoma, where abundant rainfall and runoff provide excellent potential for water resources development. The state has developed only a small portion of the estimated 34 million acre-feet of water which annually flows unused out of eastern Oklahoma into Arkansas and Louisiana, ultimately to the Gulf of Mexico. Water resources vastly exceeding any foreseeable demands remain available for development in this area.

On the other hand, central Oklahoma, which possesses the resources favorable for large-scale industrial expansion, is approaching the limit of development permitted by its available water resources and projected population growth is expected to place further pressure on existing supplies.

In western Oklahoma additional sources of water will soon be required to supplement or replace the depleting ground water resources presently used to irrigate fertile farmlands and to expand irrigation. It is estimated that some areas will expend their water supplies in 20 years or less, thus causing farmers to revert to dryland farming.

The preceding chapter proposed local water develpment projects utilizing local stream and ground water supplies necessary for each of the eight planning regions to meet future water needs through the year 2040. As indicated in Figure 96, the three eastern Oklahoma planning regions have sufficient water resources, to meet their projected needs, although some have not been developed, and still have a surplus of water. However, the Central, Southwest, South Central, North Central and Northwest Planning Regions are expected to experience future water shortages of varying degrees, even after all local sources are developed. These regions must rely on other areas of the state to provide additional water supplies.

State and federal studies to date indicate that the only viable means of providing additional water to these water-deficient areas appears to be the transfer of surplus water from eastern Oklahoma. The two water conveyance systems proposed as integral parts of the Oklahoma Comprehensive Water Plan would accomplish such a redistrubution.

The statewide water conveyance system is based upon specific assumptions which include: (1) existing multipurpose reservoirs are tied into the system to maximize the use of existing development; (2) all good quality ground and stream water resources in western Oklahoma are developed to the maximum extent practical; and (3) all proposed local projects are encouraged for development so that the import requirements of each region are minmized.

In the formulation of the statewide water conveyance system, it was determined that the Corps of Engineers would be the lead agency in developing draft plans and cost estimates for the central and eastern parts of the state and the Bureau of Reclamation would have the responsibility for planning conveyance facilities in western Oklahoma. During the course of work, the Planning Committee coordinated the activities of all participants in order to utilize the results of their studies to formulate the water conveyance systems presented herein.

GENERAL DESCRIPTION

Figure 97 shows the two conveyance systems proposed as a means of assuring the entire state of adequate amounts of water through the year 2040.

The northern conveyance system would utilize surplus flows at Lake Eufaula and Robert S. Kerr Reservoir. Off-stream regulating storage would be provided at Welty and Vian Creek Reservoirs. The surplus water would then be conveyed to nine terminal reservoirs in north central and northwestern Oklahoma. The total amount of water transferred through the northern conveyance system would be 1 2 million acre-feet annually, primarily for irrigation purposes.

The southern water conveyance system, updated from Phase I of the Oklahoma Comprehensive Water Plan, would divert surplus yields from existing and authorized reservoirs in southeastern Oklahoma to central and southwestern Oklahoma. The Central Planning Region would receive 487,000 acre-feet per year for municipal and industrial use, with the proposed West Elm Creek Reservoir serving as a terminal reservoir. A turnoff near Wayne would carry 823,000 acre-feet per year of largely irrigation water southwestward to seven terminal reservoirs. Total water delivered would be 1,310,000 acre-feet per year.

Both systems would include pumping plants, pipelines and ac-

FIGURE 96 YEAR 2040 STATEWIDE WATER RESOURCES AND REQUIREMENTS
(In 1,000 Af/Yr)

REGION	PROJECTED 2040 REQUIREMENTS	POTENTIAL DEVELOPMENT	SURPLUS (DEFICIT)
SOUTHEAST	548.7	4,120.0	3,571.3
CENTRAL	819.7	332.7	(487.0)
SOUTH CENTRAL	228.8	193.3	(35.5)
SOUTHWEST	1,392.8	593.9	(798.9)
EAST CENTRAL	365.1	1,957.6	1,592.5
NORTHEAST	971.0	3,062.8	2,091.8
NORTH CENTRAL	659.9	561.7	(98.2)
NORTHWEST	1,953.5	1,006.4	(947.1)
STATE TOTAL	6,939.5	11,828.4	4,888.9

cessories to deliver municipal and industrial water from terminal reservoirs to identified demand centers. Costs of facilities to further distribute water from these demand centers and cost for water treatment facilities are not included here

The proposed irrigation distribution facilities from terminal reservoirs have been designed so that all the irrigated lands served by the system lie within one mile of proposed facilities. Lands identified for irrigation are those classified as those most suitable for long-term project-type irrigation.

STAGING

In order to minimize the cost of construction, each conveyance system is proposed to be built in stages coordinated with the increased water needs of the import regions. The initial stage of development of each system would include construction of a portion of the source components and a major segment of their respective conveyance canals, so that water would be available for use in some areas of the import regions at the end of the first stage of development. In succeeding stages additional sources of water would be developed and the import capabilities of terminal reservoirs in western Oklahoma increased until the ultimate capactiy of each system is achieved The northern water conveyance system is proposed for construction in three stages over a 30-year period, while the southern system would be completed in four stages over the same period. The systems have been designed so that by the end of the thirteenth year after initiation of construction, all counties requiring imported water will have sufficient amounts available to meet their projected demands

COST METHODOLOGY

Preliminary cost estimates for the statewide water conveyance system are based on January 1978 price levels and a 100-year period of analysis. These include (1) construction costs; (2) average annual operation, maintenance, replacement and energy (OMR&E) costs; and (3) average annual equivalent cost. No costs are included for local delivery and/or treatment of municipal and industrial water.

Construction costs include construction of proposed dams and reservoirs; water supply storage in existing, under construction and authorized reservoirs; conveyance facilities; irrigation distribution and municipal and industrial delivery facilities; and environmental mitigation/compensation costs.

Annual OMR&E costs include expenses necessary for effective operation, regular maintenance, major replacement and required energy or pumping costs. Upon completion, assurances would be obtained from a legal entity of the State of Oklahoma to accept maintenance of water conveyance system, including recreation facilities, in order to insure operation, maintenance and major replacements. Operation would include providing all personnel, equipment and materials required to operate and maintain the system. In addition, the operating entity would be responsible for the purchase of all electrical energy required to operate the system.

Maintenance, performed at the operating entity's expense, would include adequate measures to prevent significant impairment of the design capacity of the water conveyance system and to insure the safety and integrity of its various components. It would also include maintenance of public use areas and measures to safeguard their aesthetic qualities.

Replacement of large pumps, motors, valves and other major equipment, as well as repair and replacement of miscellaneous items, would be accomplished at the expense of the operating entity

Initially, consideration was given to utilizing "off-peak" energy to reduce pumping costs, however, depending on the duration of the off-peak period, such a system would require approximately two to four times the conveyance capacity of one designed for uninterrupted pumping. Since the greater capital costs required for this increased capacity would negate any savings in energy costs, operation of the system is based on continuous pumping at an average demand rate.

Pumping plants in the system would be operated on an as-needed basis. Upon completion of each stage of the project, the installed pumping capacity would exceed the immediate requirements, and the pumps would be operated intermittently as required. However, as demands increased, the idle periods would become fewer and of shorter duration until additional pumping capacity is required or until the ultimate capacity of the system is reached.

Average annual equivalent costs are presented to allow aessment of individual project features as well as the entire system on a comparative basis. This cost includes interest and amortization as well as annual OMR&E costs. It reflects the average annual amount of repayment of construction costs and interest during construction, along with OMR&E costs over a 100-year period. Except for water supply storage in existing, under construction and authorized federal reservoirs, interest during construction was computed at the federal discount rate of 6 5/8 percent. Cost estimates for storage in these reservoirs were calculated according to the federal discount rate applicable to each reservoir.

Construction Costs

DAMS AND RESERVOIRS

Cost estimates were prepared for proposed dams and reservoirs with and without flood control. Costs of clearing, relocations and rights-of-way were included in these estimates.

CONVEYANCE FACILITIES

Field cost estimates were made for each segment of the canal based upon the following features: canals, siphons, pumping plants, discharge conduits, pipelines, rights-of-way, automation and archeology. Total

FIGURE 98 SUMMARY OF COSTS STATEWIDE WATER CONVEYANCE SYSTEM (In $1,000)

WATER CONVEYANCE SYSTEM	CONSTRUCTION COST	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
Northern System[1]		
Reservoirs[2]	$ 600,000	$ 32,500
Conveyance Facilities	3,440,000	264,100
Irrigation Distribution	1,100,000	58,300
M & I Distribution	71,000	4,300
Mitigation/Compensation	85,000	5,600
Subtotal	$5,296,000	$364,800
Southern System		
Reservoirs[2]	$ 225,000	$ 8,900
Conveyance Facilities	1,425,000	129,900
Irrigation Distribution	765,000	45,400
M & I Distribution	75,000	4,400
Mitigation/Compensation	18,000	1,300
Subtotal	$2,508,000	$189,900
TOTAL	$7,804,000	$554,700

[1]Cost estimates shown for northern system assume Arkansas River Basin Chloride Control Projects operational. Costs without the chloride control projects would be $5.6 billion for construction and $375 million for average annual equivalent costs.

[2]Reflects cost of proposed reservoirs, modifications to existing lakes and water supply storage in existing, under construction and authorized federal reservoirs.

[3]Includes interest and amortization at 6 5/8 percent interest and 100-year period of analysis. Also includes average annual OMR&E expenses and mitigation/compensation costs.

field costs also included 10 percent for miscellaneous unlisted items and 20 percent for contingencies. Total construction costs for conveyance facilities also included indirect costs calculated at 25 percent of the total field costs.

IRRIGATION DISTRIBUTION SYSTEM

The irrigation distribution system provides for installation of pumping plants, canals, laterals and underground pipe from terminal reservoirs to the irrigable lands in each section. Due to the magnitude of acres involved, detailed designs and estimates were not prepared for the entire irrigation distribution system. Therefore, a per-acre cost for distribution was derived from four sample areas considered typical and results indicated an average cost of $2,150 per acre. This cost reflects top-of-the-line equipment and a small canal to each farm and under ground pipe distribution facility in the field. Since $2,150 per acre represents an average expenditure, it is anticipated that actual costs in some areas may be substantially lower.

MUNICIPAL AND INDUSTRIAL DELIVERY SYSTEM

The projected 2040 municipal and industrial water requirements from the import canal for each county were distributed to municipalities based on population projections and feasiblity for a delivery system. Communities with the largest projected populations were selected to be served. Where smaller communities were located near the selected routes, they were also served.

The aqueducts were sized to deliver the required demand 365 days a year, plus 50 percent for peaking. Communities adjacent to the canal would be served from the canal, however, no costs have been developed for such diversions

Mitigation/Compensation Costs

Major water development projects almost always result in drastic alterations in fish and wildlife habitat. Such alteration often results in a net negative impact on the fish and wildlife resources of the affected area. Mitigation of such losses ranges from measures to alleviate negative impacts to partial or total compensation based on land acquisition and management. The degree of mitigation or compensation considered appropriate for a particular project is usually commensurate with the severity of the project's unavoidable impacts. The justification for measures to prevent, mitigate or compensate for losses is based on the principle that those resources which suffer loss are made whole to the extent that is possible and reasonable. Specifically, net losses should be prevented; if that is not possible, mitigated (lessened in severity); or, as a last resort, compensated for; and in that order of priority. Since impacts resulting from inundation of habitats cannot be prevented, the remaining avenue is either mitigation or compensation. Offsetting project losses often entails land acquisition and management to increase the fish and wildlife-supporting capacity. Mitigation/compensation costs were estimated on the basis of predicted net losses of fish and wildlife habitat. These cost estimates were provided by U.S. Fish and Wildlife Service.

Operation, Maintenance, Replacement and Energy (OMR&E) Costs

Annual operation, maintenance and replacement (OM&R) costs were estimated for proposed reservoirs and proposed modifications to existing reservoirs, the main aqueduct and pertinent distribution facilities. These were based upon a rate per dollar of field costs, while those for the irrigation distribution system are based on a unit cost per acre. The municipal and industrial delivery system's OM&R costs reflect a rate per dollar of pipeline field cost.

Energy costs were estimated using a 30-mil power rate ($0.030 per kilowatt hour). Construction costs for facilities such as transmission lines

FIGURE 99
MITIGATION/COMPENSATION COSTS
(In $1,000)

CONVEYANCE SYSTEM	ACRES	DEVELOPMENT COST	ANNUAL OM&R	TOTAL AVG. ANNUAL EQUIVALENT COST
Northern System	173,328	$ 84,700	$250	$5,645
Southern System	26,300	18,000	100	1,295
TOTAL	199,628	$102,700	$350	$6,940

and substations were assumed to be covered by the power rate.

Energy requirements would be met by privately owned utility companies. Officials of major utility companies in the state have indicated that initial power requirements could be readily supplied and that future energy needs could be met as new generating facilities are constructed.

Average Annnual Equivalent Cost

The average annual equivalent cost was estimated by amortizing construction costs (including the cost of future installations) plus interest at the federal discount rate of 6 5/8 percent for a 100-year period. Interest during construction at 6 5/8 percent was included in the investment cost used in determining the average annual equivalent cost.

COST ESTIMATES

As shown in Figure 98, total estimated construction cost of the northern and southern conveyance systems is approximately $7.8 billion (assuming the authorized Arkansas River chloride control projects are operational), with an average annual equivalent cost of $555 million. Construction of the northern system is estimated to cost $5.3 billion, with $365 million in average annual equivalent costs. The southern system is estimated at $2.5 billion and $190 million for construction and average annual costs, respectively.

Figure 99 summarizes mitigation/compensation costs for both systems. A total of 199,628 acres would be purchased at a development cost of just over $100 million and an average annual cost of almost $7 million.

Estimated Value of Water

The estimated cost or value of the water conveyed through the system actually reflects the cost of conveyance and storage facilities required to provide the water. Existing Oklahoma law declares that stream water has no cost, or is essentially free, since the water belongs to the state. Therefore, the term "cost of water" discussed below implies the cost of facilities to provide a unit amount of water.

An accurate estimate of the cost (value) of municipal and industrial water conveyed through the system can be calculated only when an actual repayment schedule is agreed upon and appropriate contracts negotiated. However, a rough estimate of the average unit value of water for the 100-year period of analysis can be obtained by dividing the average annual equivalent cost attributable to municipal and industrial water by the ultimate municipal and industrial capacity of the system. This method indicates an average value per thousand gallons of 30 cents in the southern system and $1.60 in the northern system. However, this represents only the average value, and does not reflect the high unit cost during the early years of the project, when a substantial portion of the first cost would be incurred and the capacity of the system would be relatively small. The cost of water to users would increase as distance from the source increases, and the consumers' cost would further ncrease as charges for local distribution and treatment are included.

A rough estimate of the value of irrigation water can be obtained by dividing the cost attributable to irrigation by the amount of water conveyed through the system for irrigation purposes (less conveyance losses). This crude estimation method presents a cost per acre-foot of $200 in the southern system and $335 in the northern system. This value includes the allocated cost for transportation and storage of irrigation water as well as irrigation distribution facilities from terminal reservoirs to the irrigated areas. Again, this value reflects merely an average over the life of the project, and would vary depending on the point of diversion from the canal and the distance from reservoir to farm. During the initial phases of the project, the unit cost would be substantially higher.

BENEFITS OF THE STATEWIDE SYSTEM

To determine the economic feasibility of the system, the benefits accruing to the project must be estimated, then compared to the project cost. At this early planning stage, a detailed benefit evaluation to determine the overall economic feasibility of the project has not been prepared. However, a rough approach can be utilized to estimate project benefits. This approach asesses only primary benefits, while in reality indirect or secondary and tertiary benefits would also accrue from a water conveyance system.

Average annual direct benefits from both systems are estimated at $122.6 million, with municipal and industrial benefits totaling $97.9 million and irrigation benefits $24.7 million.

Municipal and Industrial Benefits

The assumption utilized in determining an estimate of municipal and industrial benefits is that the benefits equal the average annual equivalent cost of the least costly alternative capable of providing the amount of water necessary to fulfill user requirements. This assumption reflects the philosophy that delivered municipal and industrial water is worth at least the cost of developing and delivering it to the users. Therefore, the average equivalent costs and benefits are assumed to be equal, giving the municipal and industrial component of both systems a 1:1 benefit-cost ratio. More detailed municipal and industrial benefit analyses may indicate that benefits would actually exceed cost, in which case, the benefit-cost ratio would be greater than 1:1.

Irrigation Benefits

Irrigation benefits were estimated according to federal planning guidelines, which involves determining net farm incomes without water conveyance (dryland farming) and with water conveyance (irrigation farming). The difference between the two represents the primary benefits attributable to the cnveyance systems, and although secondary and tertiary benefits would also occur they are not included in this analysis.

Calculation of irrigation benefits was based on agricultural areas defined by the Oklahoma State University Extension Service. Historical data from the "Census of Agriculture" and "Oklahoma Irrigation Survey" were utilized to estimate cropping patterns and irrigation changes. Oklahoma State University farm management specialists in each area provided projections on probable future cropping patterns and yields. Farm budgets from Oklahoma State University were used to assess current farming and irrigation pratices.

In the future "without" analysis, the approximately 900,000 acres projected for irrigation from the conveyance system were assumed to be under dryland farming. To determine benefits under dryland conditions, an enterprise budget analysis was prepared which developed per-acre crop net farm returns. These returns were then prorated to arrive at an average per-acre net farm income. In the analysis, it was assumed that cropping patterns and yields would remain relatively constant. Prices received were October 1977 Current Normalized Prices, while prices paid were current 1977 prices as reported by the farm management specialists. Total farm production expenses were increased by the same percentage as the increase in crop production.

In the future "with project" analysis, over 1.6 million acre-feet of water per year would be supplied for irrigation purposes from both systems combined. Irrigation benefits were determined utilizing similar enterprise budgets as above to derive average per-acre net farm income. Assumptions in this analysis included: (1) irrigation would be accomplished through the existing mix of gravity, side-roll and center pivot systems; (2) irrigation development would be timed so that whenever water became available, the lands would be prepared; (3) crop yields would be equivalent to the present yields obtained by the best farmers, which would be typical in the future; (4) production costs would increase by the same percentage as the increase in crop production; and (5) no appreciable double-cropping would occur.

Primary annual benefits were then calculated as the increase in net returns between the "without" and "with" project alternatives. Results of this method indicated total annual irrigation benefits of $35.2 million and $34.2 million for the northern and southern systems, respectively. These benfits were calculated assuming all project facilities were completed and in full operation. To reach a more realistic analysis, benefits were discounted to allow for a development period, which decreased primary annual benefits to $16.7 million (or $32.60 per acre) in the northern system and $8 million (or $20.20 per acre) in the southern system.

The smaller average annual equivalent benefits from the southern conveyance system are the result of the acreages irrigated with import water coming on line later in southwestern Oklahoma than in the northwest. Thus, benefits from the southern system cannot be counted for as long a period as those from the northern system.

BENEFITS-COST ANALYSIS

A comparison of benefits with costs enables the economic feasibility of a project to be determined. Under federal guidelines, benefits must equal or exceed costs in order for a project to be considered economically justified and thus eligible for construction. Average annual equivalent benefits accruing from the northern water conveyance system and the southern conveyance system indicate that neither system is economically justified under federal criteria, which recognize only primary benefits.

More specifically, the irrigation component of each system is economically unjustified since the returns from irrigation are not sufficient to completely offset the cost of water.

Indirect benefits from the system will most assuredly occur, although they have not been assessed at this time. These indirect impacts take the form of stimulated agribussiness activities such as increased sales of agricultural chemicals and farm machinery and higher production by food processors. In addition, local retail sales would increase, land values probably would rise and fiscal services probably would increase to meet growing demands.

A Statewide Economic Impact Study currently underway by the University of Oklahoma and Oklahoma State University, under the direction of the Oklahoma Water Resources Board, will quantify these indirect impacts, thus increasing the benefits of the system. Further evaluation may show the system to be of sufficeint economic benefit to justify the state's subsidizing that portion of the project's cost which is not considered feasible under federal guidelines, or perhaps to wholly assume the cost of the water conveyance system.

PAYMENT CAPACITY ANALYSIS

The payment capacity analysis involves determining the amount from net farm income under the "with" project (or irrigation alternative) that would be available to the farmer for payment of the project water cost. An allowance for increases in equity, family labor, and management and dryland net farm income is deducted from the irrigated income to arrive at an estimate of payment capacity.

This analysis reflects a short-term transition period which represents the period necessary for the farmer to become adapted to irrigated farming. Therefore, it was assumed that crop yields in each region would be somewhat lower that those projected for the benefit analysis.

Results of this evaluation indicate the average payment capacity for the farmer would be appoximately $44 per acre in the northern system and $30 per acre in the southern system.

SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS

Initial environmental impacts of the proposed statewide water conveyance system would be attributable to construction activities, which would temporarily or permanently disrupt or destroy vegetation and natural habitat. Most seriously affected would be the floodplains lying within the proposed construction areas, especially those of eastern Oklahoma which support diverse forests and a variety of habitat. Due to fewer plant and animal species and the previous conversion of virgin land to highly developed agricultural lands, the enviromental impact on western Oklahoma could be somewhat less.

The noise and dust attendant to construction, the disturbance of vegetation and wildlife, and the disruption of aesthetic values would be temporary, and therefore would terminate with the completion of construction.

The canals, siphons and pipelines required by the statewide water conveyance system would extend approximately 1,130 miles in total length and require an estimated 24,000 acres of land. Rights-of-way for the system would have to be acquired by purchase of federal, state and private lands which would change land use and convert private ownership to public.

The extensive inundation of land by reservoirs is inevitable in any major water development project. Conservation storage in proposed new source and terminal reservoirs proposed as parts of the water conveyance system would inundate approximately 177,000 acres of land, including broad expanses of productive bottomland. The significant loss of tax revenues from such land is expected to be at least partially offset by income from increased recreational and commercial opportunities provided by the reservoirs. Assuming federal participation in construction of the system, provisions of P.L. 565 which provide "payments in lieu of taxes" to local governments for land removed from the ad valorem tax base, would also partially offset losses.

In addition to federal compensation, Oklahoma Statues provide for similar payments to the local area. Title 82 O.S. Supp. 1974, Section 1086.1 requires that the purchasing entity pay to the county of origin, in lieu of ad valorem taxes, an amount equal to the existing taxes on land removed from the tax rolls as a result of construction of storage facilities.

Preliminary investigations indicate that numerous archaeological sites lie within the proposed rights-of-way. More comprehensive planning will identify those sites and develop measures to minimize losses. The removal and preservation of finds possessing significant scientific or social value would somewhat mitigate losses of archaeological sites.

Although numerous Oklahoma historical sites are listed in the National Register of Historic Places, none would be affected by the statewide water conveyance system.

Completion of the proposed system would make available to central and western Oklahoma additional water of significantly higher quality than that presently provided by local streams and ground water basins. While much of the local water presently exceeds standards for total dissolved solids, chlorides, sulfates and other parameters, the import water would meet existing criteria for drinking water. A water supply augmented by additional quantities of high quality water would enhance social and economic development by insuring a more dependable agricultural and industrial economy. Releases of high quality water from terminal storage reservoirs could improve the water quality downstream and thereby enhance downstream fisheries.

Although the evaporation of water during transit would vary with the amount of water diverted and the season, such losses are expected to have only insignificant effects on the concentration of dissolved solids in the imported water. The amounts of water lost annually to evaporation along the water conveyance route should remain relatively uniform.

The selected water conveyance system would not have an appreciable short-term effect on property values, although some land speculation can be anticipated. Land severed by a canal may decrease in value, but lands underlain by pipeline should not experience depreciation.

Although the system would require the relocation of some families presently living along the canal route and in the areas proposed for reservoir sites, adverse effects on owners and residents would be mitigated. Assuming federal participation, such compensation would be determined and paid for lands, improvements and moving costs according to the Uniform Relocation and Land Acquisition Policies Act of 1970 (Public Law 91-646). Displacements would have only short-term effects, and no families would be displaced after project construction.

Community cohesion could be disrupted temporarily by the influx of construction workers and their families and by the resettlement of families displaced by the project. Project workers would be expected to distribute themselves throughout the construction periphery, and other impacts would be minimized by their spread over such a large area.

Some long-term disruption in community cohesion could be expected as a result of severance of land ownerships by the canal. However, construction of the water conveyance system could increase stability in central and western Oklahoma, where families pressured by water shortages might otherwise abandon their farmlands. Oklahoma's agricultural economy would be enhanced by the increased crop yields made possible by the availability of irrigation water.

The construction of the canal and associated reservoirs would stimulate local economies and provide local residents with greater employment opportunities, through planning and construction activities and into the maintenance and operation period. Such strong favorable effects could be expected to continue through construction and into the operation stage.

Construction of the system would increase tax revenues, with the influx of construction workers contributing income and sales taxes. Long-term sales tax and property tax revenues should rise also.

As population densities increase, shopping and service centers would be built, and industrial complexes would develop. Homes, streets, roads, power facilities and water and sanitary systems would be needed by growing populations. Taxing entities would experience increases in tax rolls, property evaluations and revenues, offset somewhat by the costs of additional governmental, educational and public services.

Effects on Fish and Wildlife Resources

The U.S. Fish and Wildlife Service expressed concerns regarding the potential adverse impacts of the statewide water conveyance system on Oklahoma's fish and wildlife resources. A list and brief discussion of USFWS concerns follow.

1. Losses of fish and wildlife habitat

Of greatest concern is the inevitable loss of riparian, floodplain and wetland habitats resulting from construction and impoundment of proposed source and terminal reservoirs.

The USFWS Division of Refuges is considering the establishment of a National Wildlife Refuge along the Deep Fork River to protect and preserve portions of the wetlands and floodplain forests, one of the few stands of such forest remaining in Oklahoma. The refuge area under study includes the floodplain of the river from the Okmulgee Game Management Area upstream into Lincoln County. Of all sites considered on the Deep Fork River, the proposed Welty Lake was determined to have the least potential adverse impact on the proposed refuge.

Although the rights-of-way of the proposed canals, pipelines and pumping plants would affect almost all types of wildlife cover, upland cover would suffer greatest losses due to the ridgeline alignment of the conveyance facilities. Upland cover includes oak and hickory forest; postoak and blackjack oak forest; and stands of mesquite, juniper, hackberry, plum and other shrubs; native and imported grasses and croplands. Bottomland cover, riparian, floodplain forest and floodplain wetlands would also be altered along the canal routes, primarily at and adjacent to stream crossings. Wildlife habitats lying within the rights-of-way would be altered, and their value to land animals and birds reduced.

At many of the system's reservoir sites the major concern would involve stream habitat, rather than terrestrial habitat. Although direct and indirect losses of stream fisheries are expected to occur temporarily during reservoir construction, these lakes would provide increased fishing upon completion. Since most of the tributary streams in western Oklahoma have little or no flow and stream fishery is marginal at best, the largest direct losses to stream fishery would occur in eastern Oklahoma. Western Oklahoma's most abundant fish populations are found in man-made lakes and major streams such as the Red, Washita and Canadian Rivers.

2. Deleterious impacts on threatened or endangered species or their habitats

Several species classified threatened or endangered by federal wildlife authorities could be potentially affected by components of the water conveyance system.

The bald eagle has established important winter roosts and feeding sites at several of Oklahoma's large reservoirs, including Keystone, Eufaula, Kaw and Great Salt Plains. Changes in reservoir operation could have adverse effects on the eagles which depend on downstream released flows, shallower upstream reaches and river portions of these reservoirs for feeding habitat.

The peregrine falcon may also live in areas around the reservoirs, but a determination of possible impacts would require further investigation.

The general topography and limestone formations along Vian Creek suggest the possible presence of caves. Should caves inhabited by threatened or endangered bat species be discovered in this area, possible impacts on those rare species would require further investigation

Although presence of the black-footed ferret in Oklahoma is uncertain, it may exist in association with larger prairie dog towns in the west. If its presence were established, the species could be adversely affected by further conversion of prairie dog habitat to irrigated croplands.

Salt Plains National Wildlife Refuge has been recently designated as critical habitat for the whooping crane. The construction of Alva Lake, proposed on the Salt Fork of the Arkansas River, could possibly exert adverse impacts on the whooping crane by reducing flows into Great Salt Plains Lake.

3. Impairment of the operational efficiency of existing public fish and wildlife installations

Game management and public hunting areas administered by the Oklahoma Department of Wildlife Conservation on many of the existing reservoirs included in the water conveyance system could be affected by the system.

Raising of pool level elevations proposed at Canton, Fort Supply and Altus Lakes would inundate parts of the Canton Game Management Area and Migratory Bird Refuge, Fort Supply Hunting Area and Altus Public Hunting Area, respectively. Optima Public Hunting Area and National Wildlife Refuge, Washita National Wildlife Refuge at Foss Reservoir and the Fort Cobb Public Hunting Area and Fish and Game Management Area could also be impacted by major deviations in pool levels.

Public hunting areas included in the Sequoyah National Wildlife Refuge on the upstream portion of Robert S. Kerr Lake are also maintained by the ODWC. Pumping plants, intake mechanisms and conveyance facilities locatd within these areas could conflict with ongoing management programs.

4. Loss of animals in open canals, coupled with blockage of movement patterns

Losses of individual animals to drowning and/or entrapment in the open canals could threaten the populations and community structure of some land animals. The canals could also prove barriers, limiting the natural movement patterns of certain animals. However, if the animals' ranging patterns can be ascertained, adequate provisions could be made for crossings and the losses to drowning could be minimized by fencing the rights-of-way.

5. Entrapment of aquatic organisms

Pumping plants and intake facilities would be located at all source and holding reservoirs and at intermediate points along the conveyance route. During the intake of water such installations may physically impinge and/or entrain fish eggs and fry, as well as other aquatic organisms. Close cooperation with the U.S. Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation during advanced planning, design and operation of the intake and pumping facilities would be necessary in order to minimize adverse impacts.

6. Possible degradation of water quality

Construction of facilities in or across existing flowing streams would initially increase turbidity down stream, but such temorary turbidity would have no significant effect on sedimentation in down-stream lakes or on fish and wildlife. Quality of water could be reduced during such periods of turbidity, and recreational activities, where they are allowed, could be temporarily impaired.

Since the water conveyance system would increase irrigation opportunities, some concern has been expressed regarding the effects of irrigation return flows on water quality. Past studies have shown some deleterious effects from increased nutrient levels and salt loads in runoff entering natural aquatic systems. However, due to the excellent quality of the water proposed for transfer, this should not be a significant problem.

7. Fluctuation of water levels in source and terminal reservoirs

Rapid fluctuations in pool levels in source and terminal reservoirs could have profound effects on fisheries, especially during the spawning season. Rapidly lowered pool levels can drastically reduce the shallow peripheral waters required for spawning, thereby causing high mortality of eggs and fry left stranded. Such impacts could be at least partially alleviated by coordinating the pumping of water with spawning activities, thus maintaining stable water levels during critical periods

8. Impacts on streamflows

Alteration of instream flow usually attends major development of stream water resources, and reductions in the volume or frequency of downstream releases below the proposed reservoirs in the water conveyance system should be anticipated. Such reductions of instream flows could adversely affect downstream aquatic and terestrial systems, causing losses in productivity and decreased diversity of fish and wildlife resources.

Serious impacts on tailwater and stream fisheries could occur, especially below Eufaula, where the striped bass fishery could be critically affected.

Moyers Dam, a low-water dam proposed on the Kiamichi River immediately downstream from the Moyers pumping plant, would be necessary to insure that pumping intakes would be adequately submerged. A major concern is the effect of the dam on a striped bass fishery proposed for the Kiamichi River and Hugo Lake. A fish passageway in conjuction with the dam is planned for inclusion in the southern conveyance system, so that the migration of striped bass and other species during spawning will not be affected.

Altered streamflow could also adversely impact segments of riparian habitat downstream from dam sites. Floodplain forests and associated wetlands, as well as other riparian cover, depend upon periodic flooding, and because some flood flows would be intercepted by the reservoirs, an alteration in the moisture regime of the downstream floodplains is to be expected. It could result in a lowering of the water table and thus a reduction in the extent and development of the riparian habitat. Decreases in frequency and volume of flooding would probably also prompt accelerated clearing and draining in downstream floodplains. The U.S. Fish and Wildlife Service has urged that storage be provided for minimumm instantaneous releases in all reservoir components.

Any significant effects on fish and wildlife resources attributable to construction and operation of the water conveyance system could be assessed by the USFWS, and where significant adverse effects are inevitable, mitigation measures incorporated. Otherwise, losses have been included in the costs of the system.

Recreational Potential

Interest and participation in Oklahoma's water-related recreation are high, as evidenced by growing numbers of visitors to the state's lakes each year. Surveys included in the Oklahoma Comprehensive Outdoor Recreation Plan show that an insufficient number of areas and facilities are available, and that existing areas will prove inadequate to accommodate the number of future visitors anticipated. Any new lake with recreational potential would attract additional visitors.

Although project roads or abandoned roads terminating at the water's edge would provide access in the absence of more complete facilities, developed public use areas would be a more desirable alternative. Such developments would concentrate visitors for more effective control, improve the recreational experience and preserve the environmental integrity of the project. Water conveyance via canal would require long, nearly level reaches and maintenance roads paralleling the canal. In planning the water conveyance system, consideration was given to the development of maintenance roads to serve the second purpose of recreational trails, with parking and sanitary facilities along the routes. Since the proposed system would extend through a variety of landscapes, such roads would offer excellent potential as hiking and bicycling trails

Proposed recreational development, presently proposed only in the southern conveyance system, includes four public use areas on West Elm Lake and a 10-mile hiking and biking trail along the main aqueduct from Lake Stanley Draper and West Elm Lake to Lake Thunderbird.

Although no recreational facilities are included in other segments of the statewide water conveyance system, consideration of their benefits should be included in future evaluations.

THE NORTHERN WATER CONVEYANCE SYSTEM

Water Requirements

As discussed in the "Regional Analyses," two of the four regions in the northern 44 counties of Oklahoma are expected to experience future water deficits. Projections for the Northwest and North Central Planning Regions indicate an import need of approximately 1,050,000 feet per year by 2040. Nearly 1.2 million acre-feet of water would be imported annually via the northern conveyance system to meet this demand and provide for conveyance losses.

Potential Sources for Transfer

The projected water supply needs of northeastern and east central Oklahoma indicate that the majority of the water supply storage in the existing, under construction and authorized lakes, as well as other potential lakes, will be utilized locally by the year 2040, thus offering only limited prospect as a source of water for transfer to north central and northwestern Oklahoma. The scattered locations and relatively small dependable yields of other potential lakes limit their viability as sources for the large amounts involved in any water transfer plan. Preliminary work revealed that only those reservoirs with large amounts of hydroelectric power and inactive storage appropriate for reallocation to water supply storage, and the surplus flows on the Arkansas River and its tributaries, offered viable sources for the projected 1.2 million acre-feet annual requirements of northwestern and north central Oklahoma.

POWER AND INACTIVE STORAGE

Power and inactive storage in two existing reservoirs, Keystone and Eufaula Lakes, offer potential sources of large quantities of water for transfer, assuming that such storage could be reallocated to water supply. Tenkiller Ferry Lake was not considered, due to the expressed desire of local interests to utilize the power storage in that project for future water supplies within northeastern Oklahoma. Transfer of water from the Grand River above Fort Gibson Dam to areas outside GRDA jurisdiction is precluded by state statutes, so power and inactive storage in the Grand River lakes was not considered as a source of transfer water. Because projections indicate Kaw Lake will be needed to meet the surrounding area's future water requirements, its power storage was likewise not considered.

The power and inactive storage in Keystone and Eufaula Lakes is expected to be essentially depleted by sedimentation by about the year 2060. If the storage were reallocated to water supply, Eufaula could supply the import requirements of northwestern Oklahoma until approximately 2020. The addition of Keystone, assuming the Arkansas River chloride control projects to be operational and quality improvements accomplished, would extend that time frame to about 2025. After that, additional sources would be necessary to meet the export requirements. Reallocation of power and inactive storage would essentially eliminate hydroelectric power production from Keystone and Eufaula Lakes, as well as significantly reducing downstream flows.

The loss of dependable yield from the reallocated power and inactive storage caused by sedimentation of Keystone and Eufaula could be offset by providing sufficient pumping capacity at the diversion site and offsite regulating storage. Surplus flows could be diverted when available ("scalping"), with the declining yield from converted power and inactive storage gradually replaced by increasing the capacity of the "scalping" facilities.

SURPLUS FLOWS ON ARKANSAS RIVER

Approximately 22 million acre-feet of water annually flows out of Oklahoma into Arkansas via the Arkansas River. Although much of it has been used for hydroelectric power generation and navigation flows, stream flows in excess of plant capacity at the hydroelectric plants on the river are not uncommon. A large part of the average flow leaving Oklahoma is the result of unused flood flows.

The importance assigned to hydroelectric power by state and Federal governments will be a primary factor in determining the availability of large quantities of water for diversion from the Arkansas River system. Decisions regarding amounts of water which can be diverted in conjunction with the hydroelectric power uses will depend on the need for and value of hydroelectric power, locations of diversion points and amounts and frequencies of diversions. If major diversions were made above a power plant only when flows exceeded plant capacity, the full generating capacity would be maintained, but the dependability of the diversions would be extremely limited. Diversions made during lower flows would reduce power generation downstream.

Present estimates of flow requirements for operation of the McClellan-Kerr Arkansas River Navigation System show that minimum flows of 530 cfs and 200 cfs will utlimately be required on the Arkansas and Verdigris Rivers, respectively. Therefore surplus flows for the purposes of this study were considered to be those in excess of the minimum requirements for hydroelectric power generation, navigation, or other established purposes. Flows in excess of 10 percent of plant capacity at the hydroelectric plants in the system were considered surplus, although the use of such surplus would necessarily result in minor losses of power production. The economic impact of such losses would have to be considered in the evaluation of any proposed diversion plan.

Water quality in parts of the study area greatly restricts the use of stream flows. The waters of the Canadian, North Canadian and Deep Fork Rivers above Eufaula Lake; the Cimarron River; and the Arkansas River from Tulsa to the mouth of the Salt Fork are of fair to poor quality for municipal and domestic uses. The water typically contains excessive amounts of dissolved minerals from natural sources upstream and/or polluted wastewater. These minerals also impair the chemical suitability of the water for irrigation, although water in the Canadian River Basin usually remains suitable. Because of dilution from higher quality flood flows, Eufaula Lake and impoundments on the Deep Fork River would provide raw water of acceptable quality for most purposes.

Water from the Verdigris and Caney Rivers and some of their tributaries does not meet accepted water quality standards because of occasional high concentrations of dissolved minerals. However, impoundments on these streams would provide raw water of acceptable quality for most purposes. In addition, many other area streams are of good quality and suitable for most uses. The Grand and Illinois Rivers produce an average of nearly six million acre-feet of usable water annually.

The quality of Arkansas River flows downstream from Keystone Dam is significantly improved by dilution from intervening runoff. At Muskogee, the quality is suitable as a source of municipal raw water supply about 65 percent of the time with chloride concentration, the controlling water quality parameter, exceeding 250 milligrams per liter (mg/L) about 35 percent of the time. Farther downstream, just past the Oklahoma-Arkansas state line (near Van Buren, Arkansas), the quality is suitable for municipal raw water supplies about 87 percent of the time, with the chloride concentration at Keystone and Van Buren meeting recommended limits for irrigation water about 83 and 95 percent of the time, respectively.

Surplus water from the Arkansas River suitable for municipal, industrial and irrigation uses is limited to periods of high stream flow. High flows (flood waters) dilute the excessive chloride concentrations which occur during low flow periods, making possible the diversion of water of adequate quality. With the Arkansas River chloride control project operational and the cleanup of man-made pollution sources, the availabiltiy of surplus water suitable for municipal, industrial and irrigation uses would be greatly increased. Such improvements would permit more frequent diversions at lower rates to obtain a given volume of surplus water of suitable quality.

If surplus waters are stored to provide a dependable source during periods of insufficient stream flows or when poor quality prohibits diversion, water of less desirable quality could be diverted, since it would be mixed with water of higher quality in the storage reservoir. For purposes of this study, waters with chloride, sulfate and total dissolved solids concentrations no greater than 300, 300 and 600 mg/L, respectively, were considered acceptable for diversion with the use of intermediate storage facilities. Use of these criteria provides water of suitable quality for municipal, industrial and irrigation use.

DIVERSION OF SURPLUS FLOWS

A comparison was made of the average annual diversions which could be made from surplus flows at 11 control points in the Arkansas River system. These control points were Hulah Dam, Oologah Dam, Fort Gibson Dam, Tenkiller Ferry Dam, Eufaula Dam, Wister Dam, Kaw Dam, Keystone Dam, Webbers Falls Lock and Dam, Robert S Kerr Lock and Dam and Van Buren, Arkansas. The diversions would be made to regulating storage during periods when minimum required flow is exceeded and when chloride, sulfate and total dissolved solids concentrations are within acceptable limits.

Diversions from the Arkansas River at Van Buren, Arkansas, Robert S. Kerr Lock and Dam and Webbers Falls Lock and Dam could each provide the dependable yield (approximately 1.4 million acre-feet per year, including seepage and evaporation losses) projected to serve northwestern Oklahoma. Van Buren would provide the greatest potential because it would require the least regulating storage for a given diversion capacity. However, its greater distance from the demand area, resulting in greater costs of conveyance facilities, far outweighs this advantage. Therefore, it was not further considered as a viable alternative source for transfers. Webbers Falls would require the greatest amount of regulating storage for a given diversion capacity of the three alternatives, and would have only a slight location advantage over a diversion site in the upper limits of Robert S. Kerr Lake. Therefore, the latter was considered to have greater potential as a single source for transfer.

Diversion of surpluses at neither Eufaula nor Keystone alone could reasonably provide the dependable yield required for transfers to northwestern Oklahoma. However, with the Arkansas River chloride control projects operational and man-made sources of pollution eliminated, a combination of the two sources could meet the requirements, if sufficient storage were provided in conjunction with the pumping facilities. Due to severe water quality problems in the Cimarron River, diversions at Keystone would not be practical without the chloride control measures.

Because of their greater distances from the demand area and/or their relatively low potential for surplus diversion, the Kaw, Wister, Tenkiller Ferry, Fort Gibson, Oologah and Hulah control points were determined less desirable than the control points discussed above. In addition, the surplus flows at each of these control points contribute to the surpluses available at the more desirable downstream control points.

In summary, the most appropriate single source of surplus flows for transfer would be the Arkansas River near the Oklahoma-Arkansas line, Robert S. Kerr Lake or Webbers Falls Lake. Other sources considered worthy of further study would be surplus flows from the Canadian River system available at Eufaula Lake in combination with surpluses at either Keystone Lake or Robert S. Kerr Lake. The combination with surpluses from Kerr Lake would allow those flows contributing to the surpluses on the Arkansas River from the Canadian River system to be intercepted upstream at a consequent saving in pumping costs. The Eufaula-Keystone combination could offer some advantages due to staging of construction since Keystone, the closest to the demand area, could be tapped first. In addition, the Keystone-Eufaula combination could offer cost advantages, if the power and inactive storage were reallocated to water supply and fully utilized prior to developing a scalping system for surplus flows.

Alternative Water Transfer Systems Considered

In formulating alternative plans for the northern water conveyance system, the Planning Committee for the Oklahoma Comprehensive Water Plan agreed that the Bureau of Reclamation would develop all plans and cost estimates for the system from Pumping Plant 28 westward and the Corps of Engineers would develop plans and cost estimates for the portions of the system east of Pumping Plant 28 (source component).

The alignment of conveyance facilities from Pumping Plant 28 to terminal reservoirs in northwestern Oklahoma was based on alternative conveyance routes previously developed by the Bureau of Reclamation in their statewide appraisal studies published in "Water, the Key to Oklahoma's Future." The conveyance route selected to pick up surplus water from source facilities planned by the Corps of Engineers and convey it on westward was based on modifications to these alternatives.

Alternative plans developed by the Corps of Engineers to deliver surplus water for the northern conveyance system were formulated for the water quality conditions tha would exist if the Arkansas Rive chloride control projects were opera tional and with cleanup of man-mad pollution ("with" condition) and alte natively assuming continuation o present conditions without chlorid control and cleanup ("without" con dition). Each alternative was form ulated to provide an ultimate dive sion of approximately 1.2 millio acre-feet annually and were based o preliminary estimates of net deper dable yield available from the variou sources and sizes of conveyanc facilities required. In addition, th time frame of development (construc tion) of each alternative was based o the assumption that the impor demands of northwestern Oklahom would increase over time. Furthe refinements in designs and cos estimates would be made upon selec tion of the most desirable plan(s).

Because the Arkansas River an its major tributaries in eastern Okla homa have been extensivel developed for navigation, hydrc electric power and other purposes, n suitable sites remain on these stream for the development of additiona large-scale reservoirs. Therefore, an new storage required to mak transfers to northwestern Oklahom dependable would have to be con structed in watersheds of mino tributaries. Storage provided in thes reservoirs would be used to regulat surplus flows diverted (scalped) fron the alternative sources.

Potential regulating reservoi sites were inventoried prior to form ulation of the alternative transfe plans. These sites were then screenec based on their proximities to poten tial diverion points, storage capacities and potential environmen tal effects.

Several tentative plans were screened to arrive at 14 alternatives worthy of preparation of preliminary design and cost estimates. Those alternatives are designated 1A through 8A, 1B, 2B, and 5B through 8B. The "A" designates the "with" chloride control alternatives and the "B" "without". (The absence of 3I

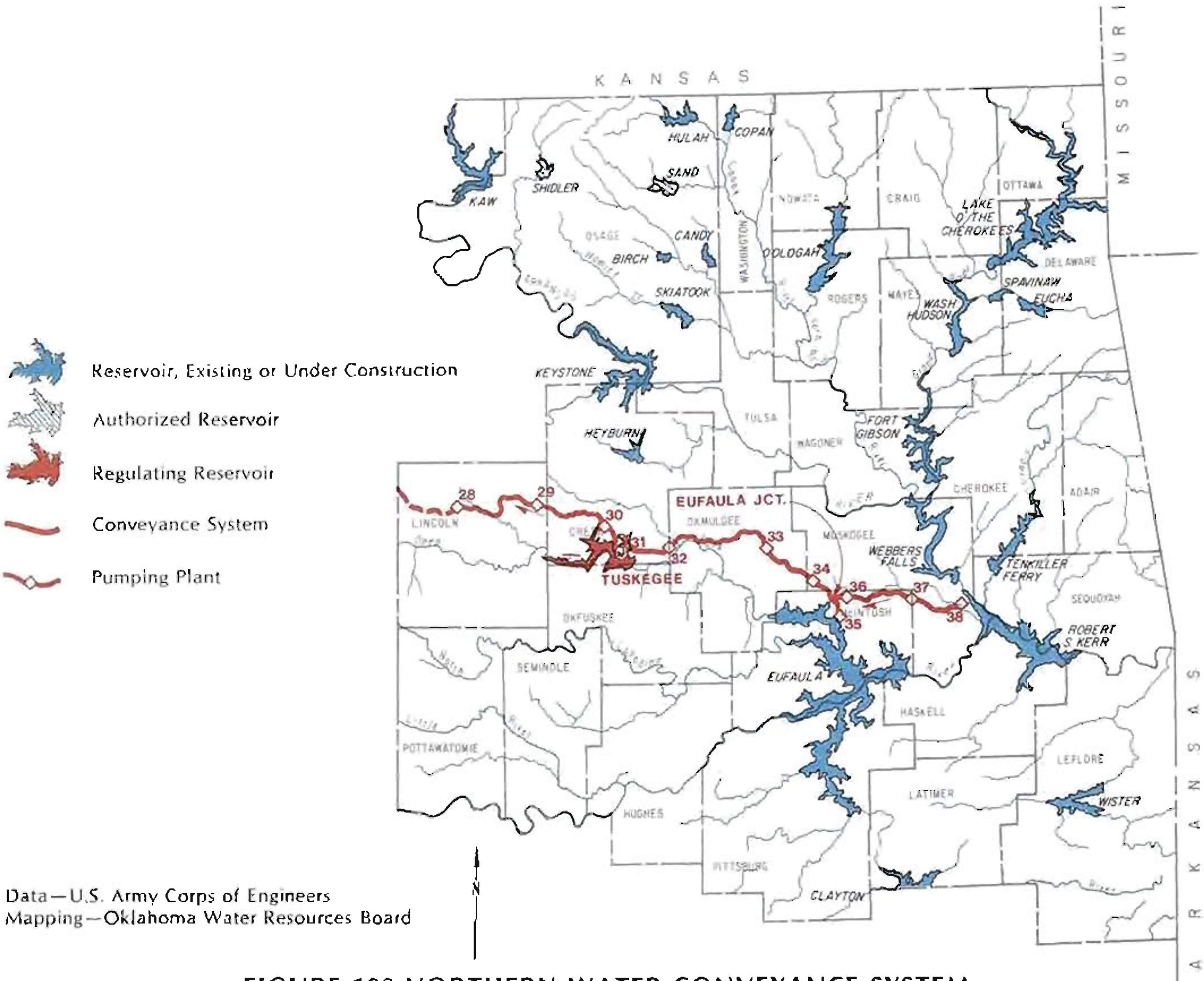


FIGURE 100 NORTHERN WATER CONVEYANCE SYSTEM SOURCE COMPONENT ALTERNATIVES 1A, 1B, 2A, 2B

and 4B is due to the lack of viable "without" chloride control alternatives to 3A and 4A.) The alternative plans are shown in Figures 100-103 and described in more detail in the following paragraphs.

Alternatives 1A and 1B (Figure 100)are based on the assumption that the power and inactive storage in Eufaula Lake would be reallocated to water supply for municipal and industrial uses and for irrigation. As discussed earlier, this source could meet the import requirements of northwestern Oklahoma until about the year 2020.

By providing regulating storage in Tuskegee Lake and increasing the pumping capacity at Eufaula Lake, surplus flows from the Canadian River system could be "scalped" at Eufaula Lake. This supply would steadily decrease because of the depletion of storage in Eufaula resulting from sedimentation. Shortly after the year 2040 the supply would fall below the northwestern Oklahoma import requirement and an additional source would be needed. To continue to meet the projected demand, a leg from the Arkansas River in the upper reaches of Robert S. Kerr Lake to the main conveyance system at Eufaula Junction would be added around year 2040. This leg would permit surplus flows at the Robert S. Kerr Lock and Dam to be diverted westward through Tuskegee Lake.

The conveyance capacity from Kerr Lake to Tuskegee would have to be greater under the "without" chloride control condition (Alternative 1B). The greater capacity is required because water of suitable quality would be available on a less frequent basis, and thus to provide the same gross yield as Alternative 1A, greater quantities would have to be diverted over shorter time periods.

Alternatives 2A and 2B (Figure 100)would be similar to 1A and 1B except that the power and inactive storage in Eufaula Lake would not be converted to water supply and a 10 percent plant factor would be maintained. These two alternatives rely on "scalping" of surplus flows, therefore regulating storage in Tuskegee Lake would be initially required in addition to the conveyance facilities from Eufaula Lake to Pumping Plant 26. The leg from Robert S. Kerr Lake would also need to be added earlier

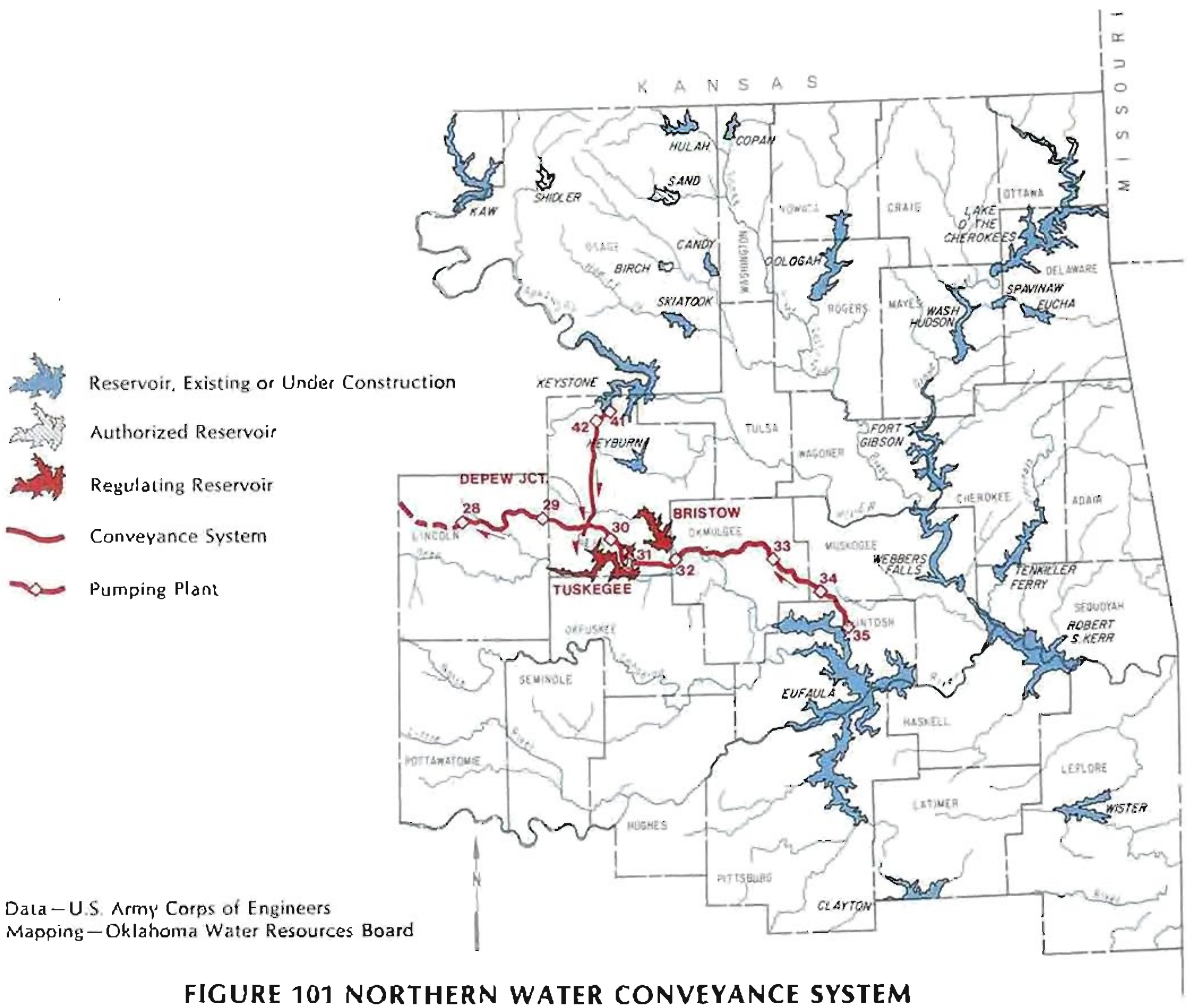


FIGURE 101 NORTHERN WATER CONVEYANCE SYSTEM SOURCE COMPONENT ALTERNATIVES 3A, 4A

(about the year 2010) because less surplus flow would be available at Eufaula Lake.

Alternative 3A (Figure 101) is based on the assumption that the power and inactive storage in both Keystone and Eufaula Lakes would be reallocated to water supply. Keystone Lake would be tapped first with regulating storage provided by Tuskegee Lake. The combination of converted storage in Keystone and added scalping capacity would provide sufficient yield of suitable quality to meet transfer requirements until about 2020, at which time the conveyance facilities from Eufaula Lake and additional regulation storage provided by Bristow Lake would be added to the system. The combined gross yield of the scalping system would ensure that the transfer requirements would continue to be met after the year 2060 when the water supply storage in Keystone and Eufaula Lakes would be depleted by sedimet.

Alternative 4A (Figure 101) would be similar to 3A except that storage in Keystone and Eufaula would not be utilized, and miminim flows for firm power generation would be maintained at the two projects With the same level of storage available in the two regulating reservoirs, greater scalping capacity would be required at the two sources to divert equivalent volumes of surplus flows during the less frequent periods when surpluses would be available and the quality would be acceptable. Under this alternative, Bristow Lake and the conveyance facilities from Eufaula Lake to Bristow and Tuskegee Lakes could be deferred until about the year 2015.

Alternatives 5A and 5B (Figure 102), like Alternatives 1A and 1B, are based on the initial reallocation of the power and inactive storage in Eufaula Lake to water supply, with eventual total reliance on scalping of surpluses at Eufaula and Robert S. Kerr Lakes when the storage in Eufaula Lake is depleted.

The conveyance facilities from Eufaula Lake westward would be the only construction initially, with regulating storage at Tuskegee Lake added about the year 2020. This combination would satisfy the pro-

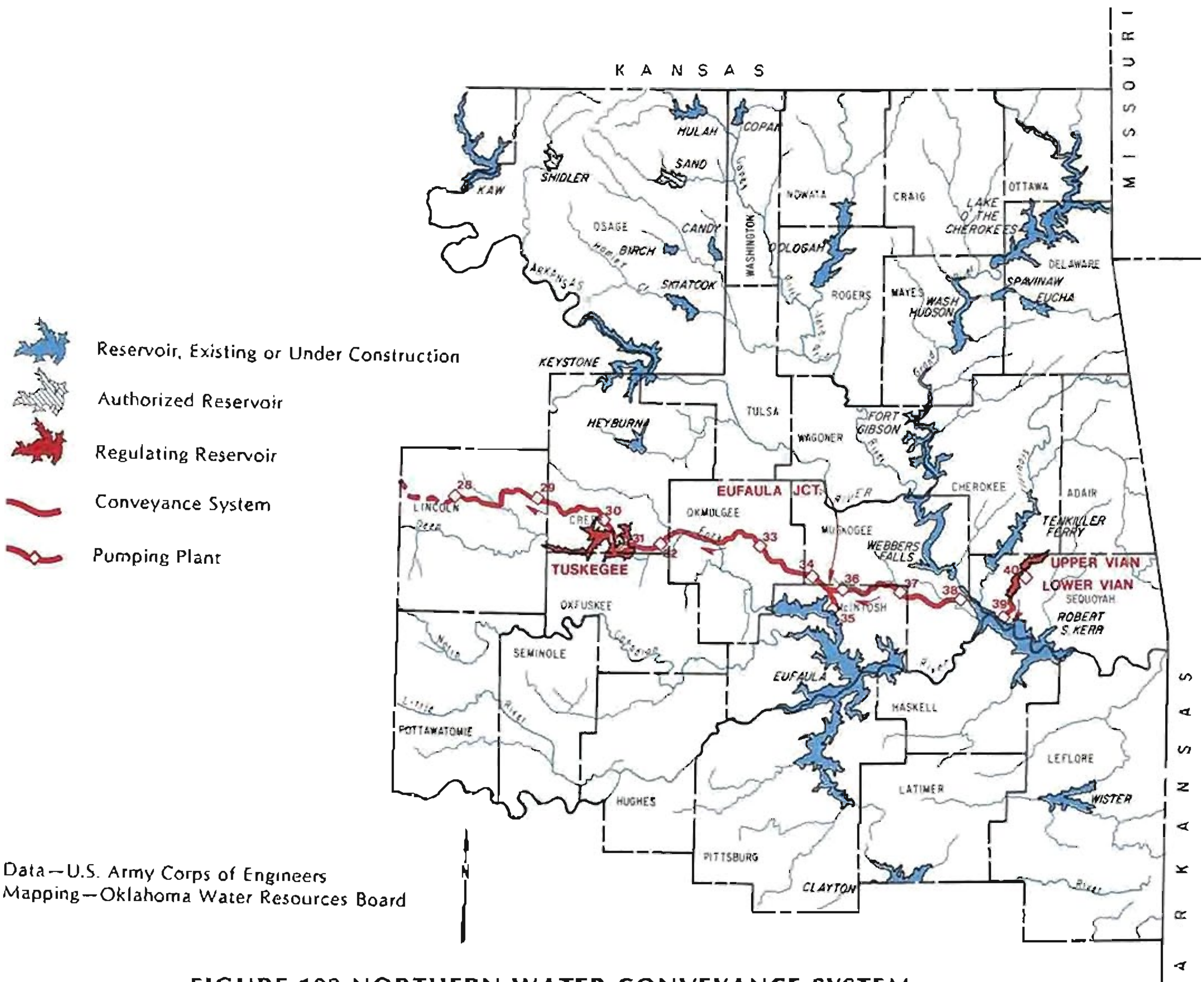


FIGURE 102 NORTHERN WATER CONVEYANCE SYSTEM SOURCE COMPONENT ALTERNATIVES 5A, 6A, 5B, 6B

jected demands of northwestern Oklahoma until about the year 2035. At that time, the leg from the Arkansas River at Robert S. Kerr Lake would be added to meet needs to the year 2040.

To continue to meet the demands beyond 2040 and make up for the depletion of storage in Eufaula Lake, two regulating storage reservoirs, Upper and Lower Vian Creek Lakes, and conveyance facilities from the Arkansas River at Kerr Lake to the regulating reservoirs would be constructed. This arrangement would also permit scalping of additional surpluses at Kerr Lake. During periods when surplus flows would be inadequate, water stored in the Vian Creek Lakes would be released to Kerr Lake via Vian Creek. Diversions equivalent to the releases would be made upstream through the main conveyance system. These two alternatives would allow part of the regulating storage to be located closer to the source, thereby reducing the capacity of a major portion of the conveyance facitlities. Greater conveyance capacity for Alternative 5B would be required because surplus water of suitable quality would be available less frequently at Robert S. Kerr Lake without chloride control. To provide the same gross yield as Alternative 5A, greater quantities would have to diverted during the less frequent periods when the quality would be acceptable.

Alternative 6A and 6B (Figure 102) would be similar to alternatives 5A and 5B except that the power and inactive storage in Eufaula Lake would not be utilized, and the releases required for a 10 percent plant factor would be maintained. Without the storage conversion and because greater minimum releases would be maintained, Tuskegee Lake would need to be constructed initially along with the full scalping capacity at Eufaula Lake. The conveyance facilities from Robert S. Kerr Lake to Eufaula Junction would be added about the year 2000, and the Vian Creek Lakes and the conveyance

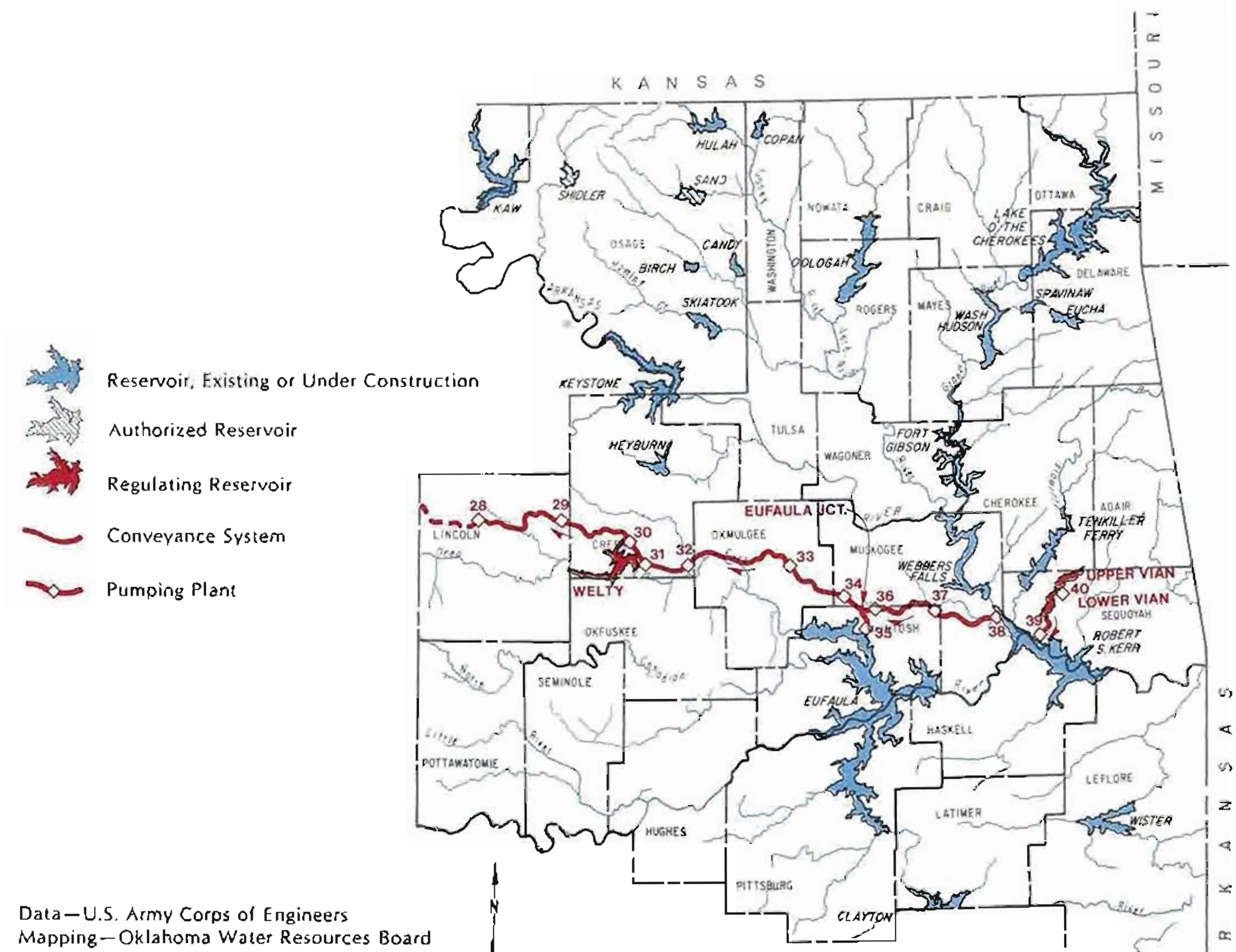


FIGURE 103 NORTHERN WATER CONVEYANCE SYSTEM SOURCE COMPONENT ALTERNATIVES 7A, 8A, 7B, 8B

facilities to those lakes would be added about 2015.

Alternatives 7A and 7B (Figure 103) would be the same as Alternatives 5A and 5B except that Welty Lake with 700,000 acre-feet of regulating storage would be constructed instead of Tuskegee Lake.

Alternatives 8A and 8B (Figure 103) would be the same as Alternatives 6A and 6B except that Welty Lake would replace Tuskegee Lake.

EVALUATION OF ALTERNATIVE PLANS

A comparison of project costs for the alternatives is presented in Figure104. The costs are based on January 1978 price levels. Average annual costs are based on 6 5/8 percent interest and a 100-year period of analysis. The average annual costs reflect staging of project components to meet preliminary estimates of northwestern Oklahoma Import demands. No costs are included for transfer facilities from Pumping Plant 26westward, since those costs will be the same for all alternatives. See Figure 104 .

A comparsion of the first costs of the alternatives shows that 6A would be the least costly of the "with chloride control" plans, and 6B would be the least costly of the "without chloride control" plans. Alternatives 5A and 5B would have the least average annual equivalent costs for the "with" and "without" conditions, respectively. It should be noted, however, that the project costs shown in the preceding table do not include the costs of mitigation/compensation of fish and wildlife habitat losses.

Prior to selection of a plan for refinement and further study, the alternatives were coordinated with all members of the Planning Committee, including representatives of the U.S. Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation. The wildlife agencies expressed major concerns about the potential impacts of several of the alternatives on fish and wildlife resources, particularly loss of unique habitats, possible deleterious effects on endangered species and potential degradation of several diverse aquatic and terrestrial habitat

FIGURE 104 ALTERNATIVE PLANS SUMMARY OF PROJECT COSTS
January 1978 Prices
(In $1,000,000)

	"With Chloride Control" Alternatives								"Without Chloride Control" Alternatives					
	1A	2A	3A	4A	5A	6A	7A	8A	1B	2B	5B	6B	7B	8B
Project First Cost														
Sources[1]	105	—	186	—	105	—	105	—	105	—	105	—	105	—
Reservoir(s)	124	124	173	173	172	172	172	172	124	124	172	172	172	172
Convey. Facilities	1,702	1,664	1,615	2,437	1,544	1,505	1,514	1,514	1,810	1,773	1,692	1,655	1,665	1,665
TOTAL	1,931	1,788	1,974	2,610	1,821	1,677	1,791	1,686	2,039	1,897	1,969	1,827	1,942	1,837
Avg. Ann. Cost														
Sources	6.8	—	6.5	—	6.8	—	6.8	—	6.8	—	6.8	—	6.8	—
Reservoir(s)	1.9	10.0	10.7	10.7	1.9	9.1	1.9	9.1	1.9	10.0	1.9	9.1	1.9	9.1
Convey. Facilities	109.9	123.9	90.8	123.8	94.1	111.6	97.7	112.4	113.0	129.5	99.0	119.8	107.4	123.6
OM&R	3.8	4.4	4.7	4.6	3.7	3.9	3.5	3.8	3.8	4.5	3.7	4.2	3.8	4.2
Energy	28.0	30.4	24.5	24.7	27.9	30.6	28.2	30.9	28.0	30.4	27.9	30.6	28.2	30.9
Benefits Foregone[2]	8.2	—	9.2	—	8.2	—	8.2	—	8.2	—	8.2	—	8.2	—
TOTAL	158.6	168.7	146.4	163.8	142.6	155.2	146.3	156.2	161.7	174.4	147.5	163.7	156.3	167.8

[1] Estimated value of hydroelectric power storage converted to water supply storage.
[2] Estimated value of hydroelectric power benefits foregone resulting from conversion of power storage to water supply storage.

parameters resulting from altered instream flows and increased lake level fluctuations, including direct impacts on stream fisheries and water quality, among others.

The U.S. Fish and Wildlife Service used a nonmonetary matrix analysis of the 14 alternatives to rank them according to their potential environmental impacts. This analysis indicated that of the alternatives considered, 8A and 8B would have the least adverse impacts on fish and wildlife resources. The alternatives with the least average annual equivalent costs (excluding mitigation costs), 5A and 5B, ranked sixth and eighth, respectively, primarily because they would severely reduce instream flows below Eufaula Lake and have greater adverse impacts on unique habitats in the Deep Fork River Basin (Tuskegee Lake area). Alternatives 7A and 7B rank seventh and tenth, respectively, for similar reasons. Although it would have a relatively high first cost, Alternative 3A would have a relatively low average annual cost, due to deferral of construction of Bristow Lake and the conveyance facilities from Eufaula Lake to Tuskegee Lake. However, Alternative 3A ranks fourteenth in the matrix analysis because it would severely reduce flows below Keystone Lake, as well as Eufaula Lake. The average annual equivalent cost of Alternatives 8A an 8B would be only 10 to 14 percent greater than the costs of 5A and 5B. The first costs would be only about five percent greater than for Alternatives 6A and 6B. In view of the preliminary nature of the cost estimates and the staging of construction for the alternatives, these fiscal differences were considered to be offset by the tangible and intangible adverse environmental effects which could be avoided if Alternatives 8A or 8B were implemented. Therefore, the Planning Committee selected Alternatives 8A and 8B to provide the base for further refinement and development of a water conveyance system for northwestern Oklahoma.

The Selected Northern System

The northern water conveyance system presented in this section is based on modification to and refinement of source Alternatives 8A and 8B and the Bureau of Reclamation portion discussed earlier. Further development of the two alternatives was coordinated with the Planning Committee for the Oklahoma Comprehensive Water Plan. Components of the system are presented for both the "with" and "without" assumptions regarding the Arkansas River chloride control project. Each component would provide the same ultimate diversion of water of suitable quality for municipal, industrial and irrigation supplies.

DESCRIPTION OF THE SYSTEM

The ultimate system as shown in Figure 97 would consist of modification of three existing reservoirs; construction of eight proposed reservoirs; approximately 710.5 miles of canals and inverted siphons; approximately 139.5 miles of pipeline; 42 pumping plants, including six with reservoir intakes; municipal and industrial delivery systems and irrigation distribution systems and all appurtenances.Figure 105presents pertinent data on the conveyance system and Figure 107shows pertinent pumping plant data. The system at ultimate development would provide a dependable water supply of 1,034,400 acre-feet annually plus conveyance losses of approximately 177,700 acre-feet from Welty Lake westward to ter-

FIGURE 105 NORTHERN WATER CONVEYANCE SYSTEM PERTINENT DATA

Reach	Design Capacity (FT^3/s)	Pipe Length (mi)	Siphon Length (mi)	Canal Length (mi)	Total Length (mi)
#1-Goodwell Turnout to Boise City Res.	566	37.5	1.0	41.5	80.0
#2-Optima Res. to Goodwell Turnout	1,108	15.0	2.8	16.0	33.8
#3-Slapout Jct. to Optima Res.	1,174	16.8	13.0	50.0	79.8
#4-Ft. Supply Jct. to Slapout Jct.	1,247	12.7	0.2	34.8	47.7
#5-Cestos Jct. to Ft. Supply Jct.	1,303	7.9	0.2	58.8	66.9
#6-Canton Res. to Cestos Jct.	1,412	0.7	0.8	10.8	12.3
#7-PP 26 to near Canton Res.	1,606	16.4	7.1	72.4	95.9
#8-Tri. Jct. to PP 26	1,606	—	6.9	27.4	34.3
#9-PP 28 to Tri. Jct.	1,851	1.7	1.7	40.4	43.8
#10-PP 31 to PP 28	1,830	2.8	6.8	51.3	60.9
#11-PP 35 to PP 31	4,000[2]	5.0	11.1	49.6	65.7
#12-PP 38 to Eufaula Jct.	4,000[3]	2.2	6.1	24.3	32.6
#13-PP 38 to Vian Creek Lake	1,000[4]	0.6	1.1	2.4	4.1
#14-Englewood Res. to Slapout Res.	57	6.1	0.1	10.0	16.2
#15-Ft. Supply Jct. to Ft. Supply Res.	26	5.1	—	—	5.1
#16-Cestos Jct. to Cestos Res.	105	8.2	0.3	26.8	35.3
#17-Near Canton Res. to Alva Res.	80	—	17.2	69.2	86.4
#18-Tri. Jct. to Sheridan Res.	160	—	6.4	42.2	48.6
TOTAL		138.7	82.8	627.9	849.4

[1]With Chloride Control
[2]Design Capacity "without" chloride control 5,180 cfs
[3]Design capacity "without" chloride control 5,200 cfs
[4]Design capacity "without" chloride control 1,300 cfs

minal reservoirs to meet the municipal, industrial and agricultural water demands of north central and northwestern Oklahoma in excess of available local sources.

Sources of water would be surplus flows from the Canadian River system at Eufaula Lake and the Arkansas River at Robert S. Kerr Lake. With the chloride control project operational and elimination of man-made pollution, the required maximum combined diversion capacity at the two sources would be 5,000 cfs. Without the chloride control project, the combined capacity would have to be 6,500 cfs. Up to 4,000 cfs of this capacity, depending upon available surplus flows and unused storage in Welty Lake during pumping periods, would be diverted at Eufaula Lake. At Robert S. Kerr Lake, diversions would be made up to maximum capacity (5,000 cfs with chloride control; 6,500 cfs without), depending upon available surplus flow, quantities diverted at Eufaula Lake and unused regulating storage.

Of the maximum diversion capacity at Robert S. Kerr Lake, 30 percent would be to Vian Creek Lake via Pumping Plan 39. During periods when transfers would depend upon water stored in Vian Creek Lake, releases would be made from the reservoir and allowed to flow into Robert S. Kerr Lake via Vian Creek. Withdrawals equivalent to those releases would be made at Pumping Plant 38 and transferred westward.

On westward the system would consist of three existing reservoirs — Optima, Fort Supply and Canton — and six proposed reservoirs — Boise City, Goodwell, Slapout, Cestos, Alva and Sheridan. The existing Optima, Fort Supply and Canton Reservoirs would be utilized for terminal storage in addition to their current uses. Optima and Canton Lakes would not require modifications, but Fort Supply dam would be raised three feet to hold additional storage. The six proposed reservoirs would serve as terminal reservoirs for import water. Englewood Reservoir, a proposed local project, would provide supplemental water to Slapout Reservoir as well as providing storage for irrigation in the local area. The actual conveyance system would consist of concrete-lined canals, siphons and pumping plant discharge pipelines, with capacities ranging from 26 cfs to 1,930 cfs. Average annual supply of water delivered through the system would be 1,034,400 acre-feet per year, primarily for irrigation purposes. Approximately 500,000 acres would be irrigated with import water. Figure 106 shows the counties to be served by

FIGURE 106 NORTHERN WATER CONVEYANCE SYSTEM ALLOCATION OF TERMINAL RESERVOIRS[1] (In 1,000 Af/Yr)

REGION	Sheridan M&I	Sheridan Irrigation	Optima M&I	Optima Irrigation	Fort Supply M&I	Fort Supply Irrigation	Canton[3] M&I	Canton[3] Irrigation	Alva M&I	Alva Irrigation	Cestos M&I	Cestos Irrigation	Slapout[4] M&I	Slapout[4] Irrigation	Goodwell M&I	Goodwell Irrigation	Boise City M&I	Boise City Irrigation	Total
County																			
NORTH CENTRAL																			
Garfield[2]	34.3	63.9																	98.2
Subtotal	34.3	63.9																	98.2
NORTHWEST																			
Alfalfa									2.6	46.4									49.0
Beaver			0	23.8									0	90.0					113.8
Blaine[5]																			
Cimarron																	0	342.0	342.0
Dewey							0	6.6											6.6
Ellis											0	52.4							52.4
Harper[5]																			
Major							0	8.0											8.0
Texas															2.9	320.6			323.5
Woods									0.7	34.8									35.5
Woodward					14.8	1.5													16.3
Subtotal			0	23.8	14.8	1.5	0	14.6	3.3	81.2	0	52.4	0	90.0	2.9	320.6	0	342.0	947.1
TOTAL	98.2		23.8		16.3		14.6		84.5		52.4		90.0		323.5		342.0		1,045.3[6]

[1]Maximum import capabilities.
[2]Only county in North Central Planning Region served by conveyance system.
[3]Preliminary operation studies indicate yield of Canton could be reduced with construction of upstream reservoirs.
[4]Includes 36,000 AF/YR of water received from Englewood.
[5]Not served by conveyance system.
[6]Total reflects firm yield of reservoirs as well as import supplies.

the system along with their source of supply and amount of water provided. Import water, plus the firm yield of the terminal reservoirs, would meet the projected deficits.

STAGING

Because water supply demands are projected to increase over the planning period, the northern conveyance system was designed to be constructed in three stages in order to minimize the unit cost of water supplied. The initial two stages would be development of the major portion of the system's source component and construction of the main aqueduct and proposed terminal reservoirs in western Oklahoma. The last stage would include additional development of the source component to increase the system to its ultimate capacity.

The first stage, requiring an estimated five years to complete, would require development of the initial phase of the source component and construction of the main canal from Eufaula Lake to Fort Supply Reservoir in Woodward County, as well as construction of three of the proposed reservoirs in western Oklahoma and their respective branch lines to the main canal. Development of the source component would include installation of pertinent pumping facilities at Eufaula and construction of the canal from Eufaula to Pumping Plant 28. In addition, the proposed Welty Lake on Deep Fork River would be built as a regulating reservoir. The 4,000 cfs diversion capability at Eufaula combined with the 800,000 acre-feet of active storage in Welty would provide a dependable supply of 590,000 acre-feet per year at Pumping Plant 28.

Extension of the system on west of Pumping Plant 28 would require further construction of the main aqueduct and branch lines to the proposed Sheridan, Alva and Cestos Reservoirs, which would also be constructed during the first stage. Completion of the branch lines would be scheduled so that they would be capable of tying into the reservoirs upon each lake's completion. The first stage would reach Fort Supply where modification of the dam would be necesssary to increase its import capability.

As indicated in Figure 108 , the first stage of the system would have the capability of supplying enough water to meet the import requirements of the north central and northwest regions. However, many of these demands exist in the three Panhandle counties of Cimarron, Texas and Beaver. Extension of the canal to this area is not possible within the 5-year construction period of the first stage, therefore the demands of the Panhandle cannot be met in the initial stage of development. This situation is depicted graphically in Figure 108 , which shows

FIGURE 107 NORTHERN WATER CONVEYANCE SYSTEM PUMPING PLANT PERTINENT DATA

Pumping Plant No.	Static Head (ft)	Total Head (ft)	Design Capacity (ft^3/s) with cc	without cc	Ultimate Average Annual Pumpage (1,000 AF)	Average Annual Energy Required (million KWH)
1	206	255	566	—	350	133
2	124	168	566	—	352	88
3	185	247	566	—	353	130
4	263	321	566	—	356	171
5	166	195	566	—	357	104
6	112	149	566	—	359	80
7	81	108	1,108	—	690	111
8	150	174	1,108	—	691	180
9	113	181	1,108	—	694	188
10[1]	210	247	1,108	—	696	257
11	121	180	1,174	—	725	195
12	170	216	1,174	—	730	236
13	145	169	1,174	—	734	185
14	265	311	57	—	37	17
15	216	268	1,247	—	770	308
16	140	176	1,247	—	774	204
17	133	154	1,247	—	782	180
17-A	73	113	26	—	13	2
18	146	169	1,303	—	790	199
19	72	90	1,303	—	794	107
20	98	142	1,303	—	802	170
20-A	193	216	104	—	60	19
20-B	122	169	104	—	57	14
21[1]	120	139	1,412	—	879	183
22	96	123	1,606	—	954	175
23	314	356	1,606	—	961	511
24	50	75	1,606	—	970	109
25	113	148	1,606	—	974	216
26	79	108	1,606	—	976	158
27	90	111	1,790	—	1,069	183
28	96	113	1,790	—	1,080	188
29	104	127	1,810	—	1,090	182
30	64	83	1,820	—	1,100	120
31[1]	124	142	1,830	—	1,100	206
32	68	89	1,970	5,150	1,300	152
33	53	72	3,980	5,160	1,310	124
34	75	100	3,990	5,170	1,320	173
35[1]	105	124	4,000	—	682	111
36	44	65	3,980	5,180	644	55
37	84	103	3,990	5,190	652	88
38[1]	121	137	4,000	5,200	660	118
39[1]	200	308	1,000	1,300	211	92
TOTAL						6,422

[1]Reservoir Pumping Plant
cc = chloride control

that the import capability of terminal reservoirs in western Oklahoma that can be developed initially is only about 400,000 acre-feet per year. This capability is sufficient to meet the import needs of northwestern and north central Oklahoma as projected at the end of the first stage, with the exception of the Oklahoma Panhandle.

The second stage of the conveyance system would require augmentation of the source component in eastern Oklahoma and extension of the main canal to the Panhandle area, along with construction of three additional proposed terminal reservoirs. During the second stage, the import capability of the western portion of the system would "catch up" with the import demand. Figure 108 shows that by the end of the eighth year, the import capability surpasses the demand curve.

As projected demands increase in western Oklahoma, tapping of an additional source would be required to supply the necessary water. The second phase of the source component includes development of pumping facilities at Robert S. Kerr Reservoir and conveyance facilities from Kerr to Eufaula junction. (See Figure 97.) Extending the system to Kerr allows additional water to be picked up so that the capacity of the system is increased to 1,070,000 acre-feet per year at Pumping Plant 28.

The second stage would also include extension of the main aqueduct from Fort Supply Reservoir to Boise City Reservoir, the system's westernmost point. Slapout, Goodwell and Boise City, all proposed reservoirs would be constructed in the second phase of development to serve as terminal reservoirs, primarily for irrigation purposes. Optima, an existing reservoir in Texas County, would also be tied into the conveyance system. In addition, a conveyance canal from the proposed Englewood to Slapout would be constructed during this stage to provide additional water to Beaver County.

The import capability of terminal reservoirs at the end of the second stage would be 1,034,400 acre-feet per year. This capability would be sufficient to receive enough import water to meet the ultimate demands of northwest and north central Oklahoma. It is estimated that completion of this stage would occur in the twelfth year of construction.

The third and final stage of the conveyance system would provide for an increase in capacity of the source component. This would be accomplished by construction of Vian Creek Lake as a regulating reservoir, and conveyance facilities from Robert S. Kerr Lake (Pumping Plant 39) to Vian Creek Lake. This final stage would provide for a maximum annual supply of 1,173,000 acre-feet. During periods when transfers would depend upon water stored in Vian Creek Lake, releases would be made from the reservoir and allowed to flow into Robert S. Kerr lake via Vian Creek. Withdrawals equivalent to those releases would be made at Pumping Plant 38 and transferred westward. It is anticipated that this stage would not be necessary until about the thirtieth year after initial operation.

COSTS

Preliminary cost estimates for the northern water conveyance system indicate total cost of construction for the system to be around $5.3 billion with the chloride control projects in operation. This cost includes $600 million for construction of new proposed reservoirs, $3.44 billion for the conveyance canal from eastern Oklahoma to the extreme western Panhandle, $1.1 billion for pertinent irrigation distribution facilities, $71 million for municipal and industrial facilities and $85 million for mitigation/compensation costs. The average annual equivalent cost would be approximately $365 million, which includes $117 million in average annual operation,

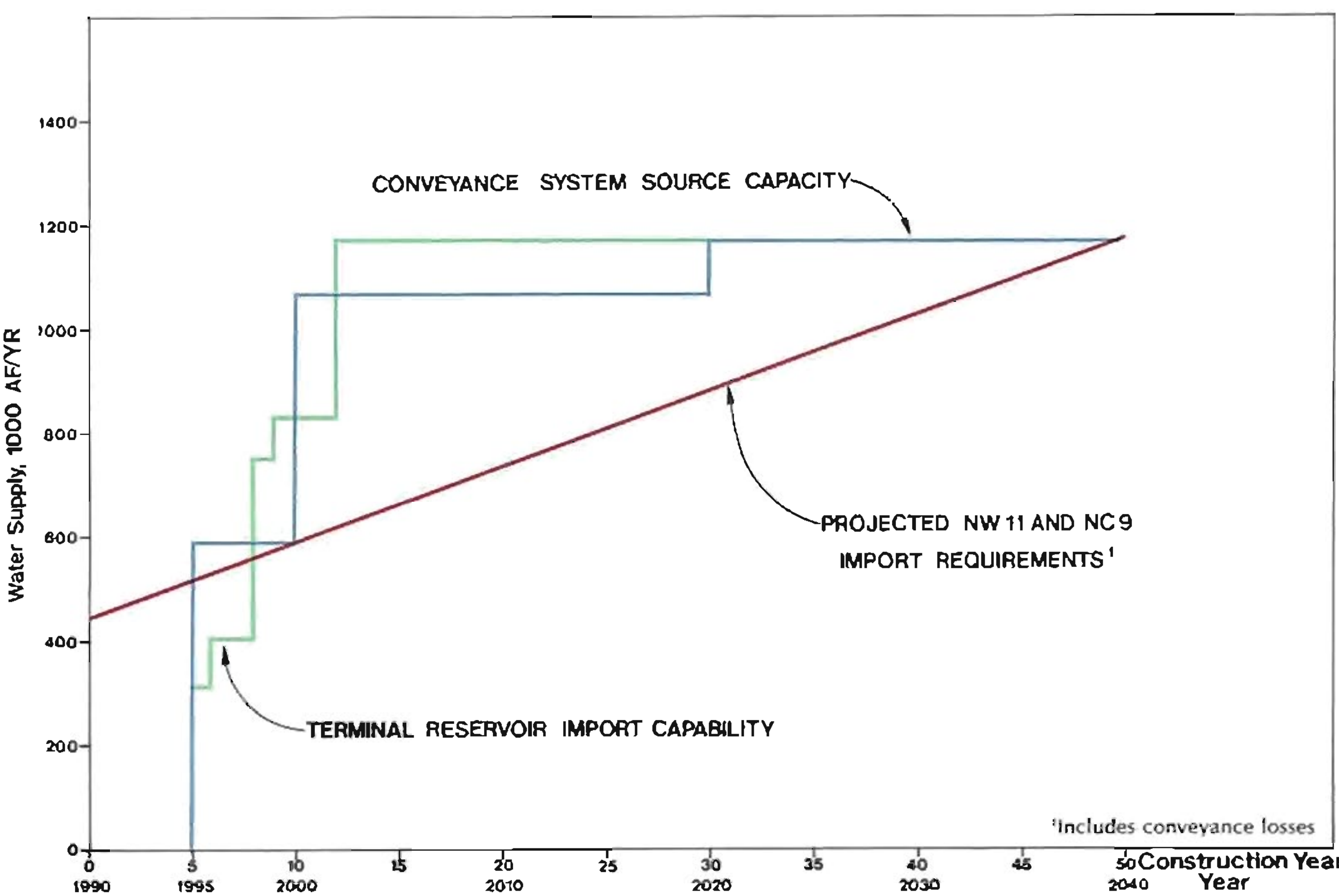


FIGURE 108 NORTHERN WATER CONVEYANCE SYSTEM CONSTRUCTION STAGING

FIGURE 109 NORTHERN WATER CONVEYANCE SYSTEM SUMMARY OF PROJECT COSTS (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COSTS[3]
SOURCE COMPONENT			
Conveyance Facilities (sources to pumping plant 28)	$1,314,000	$ 23,560	$ 95,600
Proposed Reservoirs (Welty and Vian Creek)	210,000	890	10,200
SUBTOTAL	$1,524,000	$ 24,450	$105,800
DELIVERY COMPONENT			
Conveyance Facilities (pumping plant 28 westward)	$2,125,000	$ 72,100	$168,540
Existing Reservoir (Fort Supply modification)	200	50	70
Proposed Reservoirs (Sheridan, Cestos, Alva, Slapout, Goodwell and Boise City)	390,800	4,270	22,190
Irrigation Distribution	1,100,000	14,980	58,320
M & I Distribution	71,000	690	4,280
SUBTOTAL	$3,687,800	$ 92,090	$253,400
MITIGATION/COMPENSATION COSTS	$ 85,000	$ 200	$ 5,600
TOTAL	$5,296,000	$116,740	$364,800

[1]Based on January 1978 prices.
[2]Energy computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E.

maintenance, replacement and energy (OMR&E) expenses and $5.6 million for average annual mitigation/compensation costs. OMR&E costs consist primarily of energy costs computed at a 30-mil power rate with annual requirements roughly estimated to be 6.4 billion KWH.

As shown in Figure 109, the source component of the northern system is estimated to cost approximately $1.5 billion, while the delivery component would cost an estimated $3.7 billion.

BENEFITS

Direct benefits accruing from the northern system were estimated $58 million annually, consisting of $17 million of irrigation benefits and $41 million of municipal and industrial benefits. Municipal and industrial benefits were assumed to equal the average annual equivalent costs attributable to the municipal and industrial component of the system. The irrigation benefits are of a primary nature, calculated as the difference in net income between dryland farming and irrigation farming.

BENEFIT-COST ANALYSIS

A rough comparison of direct annual benefits ($58 million) and costs ($365 million) indicates the northern water conveyance system exhibits a benefit-cost ratio of .16:1. Under federal planning guidelines, such a ratio renders a project economically infeasible and construction cannot be justified. However, considerable indirect benefits, particulary those due to agricultural and agribusiness impacts, would result from the transfer system, but which are not included in this analysis, would also need to be considered prior to a final assessment of the feasibility of the project.

SOUTHERN WATER CONVEYANCE SYSTEM

Water Requirements

Water requirement projections by the Planning Committee of the Oklahoma Comprehensive Water Plan indicate that by the year 2040, central Oklahoma will need to import 487,000 acre-feet of water annually for municipal and industrial purposes and southwestern and south central Oklahoma will require 728,500 and 28,000 acre-feet per year, respectively, primarily for irrigation purposes. A dependable supply of nearly 1,320,000 acre-feet annually would have to be developed in southeastern Oklahoma to meet the projected demands and provide for conveyance losses.

As indicated earlier, three of the four planning regions in the southern 33 counties of Oklahoma are projected to face severe water shortages in the foreseeable future. Even with full development of the proposed local water sources outlined for these three regions, they may still experience a combined import deficit of almost 1,240,000 acre-feet per year by 2040, which will have to be supplied from other areas of the state. Studies show that existing, planned and potential stream water development and ground water sources in southeastern Oklahoma could easily supply that region's projected water needs, meet the import demands of central and southwestern Oklahoma, and still produce an annual surplus of approximately 2.2 million acre-feet.

Potential Sources for Transfer

In selecting sources of water supply, potential reservoir development as well as existing and authorized reservoirs in southeastern Oklahoma were considered. These reservoirs were screened and alternatives considered which could meet the needs of all the southern 33 counties.

The abundance of water in southeastern Oklahoma provided many potential sources for evaluation. As with any water supply study, both water quality and quantity were important concerns. The major consideration in the analysis was to provide good quality water in the amount needed while minimizing the cost of conveyance facilities and storage in the overall system.

From the analysis it was determined that Clayton, Tuskahoma, Hugo and Boswell reservoirs offered the greatest potential as sources for transfer. Hugo is an existing reservoir, Clayton is under construction and scheduled for completion in 1981, and Tuskahoma and Boswell are authorized for construction.

Hugo Lake presently maintains a dependable yield of 165,760 acre-feet annually, however, once Clayton and Tuskahoma are constructed to complete the 3-lake system on the Kiamichi River, part of the flood control storage in Hugo could be converted to water supply, raising the ultimate yield to 302,800 acre-feet per year, including the yield from water quality control storage. The yield of Boswell Lake allocated for irrigation supplies (688,000 acre-feet per year) would be used in south central and southwestern Oklahoma.

Yields available for municipal and industrial water supply are based on a dependable yield through a 50-year frequency drought. Yields available for irrigation are based on a 10-year frequency drought.

Most of the water supply and irrigation storage allocated in the reservoirs would be for use in central and southwestern Oklahoma, however, some storage would be reserved in three of the four reservoirs to meet needs in the vicinity of the sources.

Alternative Water Transfer Plans Considered

The southern water conveyance system is a modification and expansion of an alternative plan developed by the Corps of Engineers in conjunction with their Central Oklahoma Project (COP) investigations. The COP water supply system investigation was authorized by congress in 1955 to determine the feasibility of transbasin diversion of surplus water from southeastern to central Oklahoma. The COP plans included alternative systems to provide municipal and industrial water to central Oklahoma via either a pipeline or open canal to meet 50-year water needs. Studies indicated that the pipeline method was actually more cost-effective than a canal when transferring water designated for central Oklahoma only. A pipeline alternative also would be less damaging to the natural environment than a canal, as well as lending itself more readily to staged development.

When the need for import water in southwestern Oklahoma became apparent, the Oklahoma Water Resources Board requested the Corps to assess the feasibiltiy of increasing the capacity of the COP plan in order to include municipal, industrial and irrigation water for southwestern Oklahoma. Consequently, the Corps designed an expanded version of the COP to provide water for southwestern and south central Oklahoma at a point where it could be picked up for utimate delivery. The Corps determined that with the increase in capacity, the pipeline alternative no longer held cost advantages over a canal alignment Therefore, an open canal system was determined the most cost-effective means of transferring water to both areas of the state.

The Bureau of Reclamation formulated two alternatives to convey water to the Southwest and South Central Planning Regions from a pickup point near central Oklahoma. The first alternative picked up the water at Wayne and then headed northwest across northern Grady County, turning straight south at the Caddo County line. From this point it split, taking most of the water westward to southwestern Oklahoma and carrying a smaller amount south to south central Oklahoma. The second alternative headed due west through northern Garvin and extreme southern Grady Counties. Near the Grady-Comanche County line, the system proposed a leg turning south, with most of the water continuing to the Southwest Planning Region. Both alternatives had the same basic alignment from Caddo County to counties in the western part of the region.

Cost analyses of the two alternatives revealed the first alternative was more costly than the second, and thus the Planning Committee decided to continue further studies utilizing the latter route.

The Bureau had initially considered another alternative to provide water for southwest and south central Oklahoma. This alternative did not tie into the Corps' system, but rather went straight to the sources in southeastern Oklahoma. This southerly route tied directly into Hugo and Boswell Reservoirs, carrying water through the southern portion of the South Central Planning Region. Then the route turned north to the upper and far western parts of the southwest region. The attractive feature of the southerly route was its independence from the canal conveying water to central Oklahoma. However, the cost of this alternative was rendered cost-prohibitive by the longer canal route and the reduced economies of scale enjoyed by combining the two canals. It is believed that if a good quality source of water could be developed closer to southwestern Oklahoma, the cost of the southerly system might be decreased sufficiently to make it a feasible alternative. Such a system would also reduce the amount of surplus water to be diverted from southeastern Oklahoma.

The Selected Southern System

The selected water conveyance system proposed for the southern 33 counties is a modified version of a Corps alternative serving central Oklahoma, along with a distribution segment prepared by the Bureau of Reclamation to transport water to the southwest. The two segments of the system would converge just east of Wayne, Oklahoma. The system was formulated under the assumption of "without" flood control storage as a project purpose.

DESCRIPTION OF THE SYSTEM

The eastern segment of the conveyance system would consist of a network of canals, pipelines, conduits and pumping plants to transport surplus water from the Kiamichi River near Moyers, Oklahoma and Hugo and Boswell Lakes to central Oklahoma and to a point near Wayne. Water diverted from the Kiamichi River near Moyers would be supplied from Clayton and Tuskahoma Lakes. Water for central Oklahoma would be pumped into existing Lake Stanely Draper and additional terminal storage would be provided through construction of West Elm Lake on West Elm Creek, adjacent to Lake Stanley Draper. The two terminal reservoirs would be connected by a gated control structure which would allow flexibility in the operation of the terminal storage.

The main aqueduct would consist of a series of six nearly level canal reaches originating on a ridge between Boswell and Hugo Lakes and terminating at Lake Stanley Draper. Six intermediate pumping plants with short conduits would be provided between canal reaches and at Lake Stanley Draper to lift water from one level to the next.

Water to the main aqueduct would be supplied through the Moyers Pumping Plant and Canal, the Hugo Pumping Plant and Pipeline, and the Boswell Pumping Plant and Pipeline. The Moyers Canal would originate near the Kiamichi River about two miles downstream from the mouth of Tenmile Creek and join the main aqueduct near Darwin, Oklahoma. The canal would be approximately nine miles long, with an ultimate conveyance capactiy of 340 mgd or 380,800 acre-feet of water per year. Water released from Clayton and Tuskahoma Lakes would be withdrawn from the Kiamichi River at the Moyers Pumping Plant and pumped through the two large conduits to the head of the canal. Moyers Dam, a low water dam, would be constructed on the Kiamichi River immediately downstream from the pumping plant to insure adequate submergence of the pump intakes.

The Hugo Pumping Plant would be located on the Hugo Lake, and would have an ultimate capacity of 260 mgd or 291,200 acre-feet of water per year. The 9-mile Hugo Pipeline would connect the Hugo Pumping Plant with the lower end of the main aqueduct.

The Boswell Pumping Plant, on the Muddy Boggy Creek arm of Boswell Lake, would have an ultimate capacity of 580 mgd or 649,600 acre-feet of water per year. The Boswell Pipeline would consist of two parallel pipelines about seven miles in length connecting the pumping plant with the main aqueduct at a point approximately seven miles north of Soper, Oklahoma.

FIGURE 110 SOUTHERN WATER CONVEYANCE SYSTEM PERTINENT DATA

Reach	Design Capacity (cfs)	Pipe Length (mi)	Siphon Length (mi)	Canal Length (mi)	Total Length (mi)
#1-Cooperton Diversion to Tom Steed Res.	140	—	—	6.1	6.1
#2-Lake Altus to Mangum Res.	136	0.7	1.0	36.5	38.2
#3-Cooperton Diversion to Lake Altus	220	1.4	1.7	33.4	36.5
#4-Cooperton Diversion to Snyder Res.	537	0.6	1.5	12.6	14.7
#5-Pine Ridge Diversion to Cooperton Diversion	915	2.5	1.3	39.6	43.4
#6-Carnegie Confluence to Foss Res.	290	4.8	9.9	57.4	72.1
#7-Carnegie Diversion Dam to Carnegie Confluence	200	0.2	0.5	3.7	4.4
#8-Ft. Cobb Turnout to Carnegie Confluence	92	0.8	—	10.8	11.6
#9-Ft. Cobb Feeder	150	—	—	2.4	2.4
#10-Pine Ridge Diversion to Ft. Cobb Turnout	242	—	3.3	10.1	13.4
#11-Verden Jct. to Pine Ridge Diversion	1,166	—	—	11.5	11.5
#12-Verden Jct. to Verden Res.	46	—	7.1	21.6	28.7
#13-Wayne Pickup to Verden Jct.	1,250	1.2	9.1	81.6	91.9
#14-Main Canal to Wayne Pickup	1,250	14.3	—	—	14.3
#15-PP 14 to PP 13	681	0.8	—	27.9[1]	28.7
#16-Moyers Canal to PP 14	1,825	2.8	—	124.9[1]	127.7
#17-PP 19 to Main Canal	526	0.3	—	9.1[1]	9.4
#18-PP 20 to Moyers Canal	1,330	6.5	—	8.3[1]	14.8
#19-PP 21 to Boswell Pipeline.	387	8.6	—	3.0[1]	11.6
TOTAL		45.5	35.4	500.5	581.4

[1]Includes siphon length

The Wayne Pipeline would consist of two parallel pipelines from Pumping Plant 5 on the main aqueduct to the Wayne dropoff point, a distance of 12 miles Pumps for the pipeline would be included in the intermediate pumping plant. The ultimate capacity of the pipeline would be 740 mgd or 828,800 acre-feet of water per year. Water for southwestern Oklahoma would be conveyed from the main aqueduct by the Wayne Pipeline to the Wayne drop-off point, from there it would be transferred to southwestern Oklahoma. The total length of the conveyance facilities to central Oklahoma would be 200 miles, and the overall lift from Hugo Lake to Lake Stanley Draper would be 800 feet. Pertinent data are presented in Figures 110 and 111 .

From the Wayne turnoff, water would be carried to southwestern Oklahoma through a conveyance system consisting of 327 miles of concrete-lined canal and 48 miles of conduit with a capacity ranging from 46 cfs to 1,250 cfs. Thirteen in-line

FIGURE 111 SOUTHERN WATER CONVEYANCE SYSTEM PUMPING PLANT PERTINENT DATA

Pumping Plant No.	Static Head (ft)	Total Head (ft)	Design Capacity (ft³/s)	Ultimate Average Annual Pumpage (1,000 AF)	Average Annual Energy Required (million KWH)
1	50	66	150	89	9
2	74	92	150	89	9
3[1]	40	56	150	89	12
4	70	92	244	145	20
5	33	51	591	352	27
6	50	66	1,006	602	59
7	147	173	1,006	602	156
N-1	220	255	319	190	72
N-2	79	98	319	190	28
N-3[1]	186	202	220	50	15
N-4	80	99	101	60	9
8	131	148	1,375	818	181
9	78	94	1,375	818	115
10	39	55	1,375	818	67
11	131	148	1,375	818	181
12	40	56	1,375	818	68
13	98	110	680	493	65
14	105	120	680	493	71
—[2]	8	170	1,150	814	170
15	98	120	1,830	1,322	192
16	110	110	1,830	1,322	176
17	96	100	1,830	1,322	160
18	115	130	1,830	1,322	208
19[1]	174	180	500	358	188
20[1]	176	220	980	706	78
21[1]	228	250	360	258	78
TOTAL					2,414

[1]Reservoir Pumping Plant
[2]Wayne Pipeline

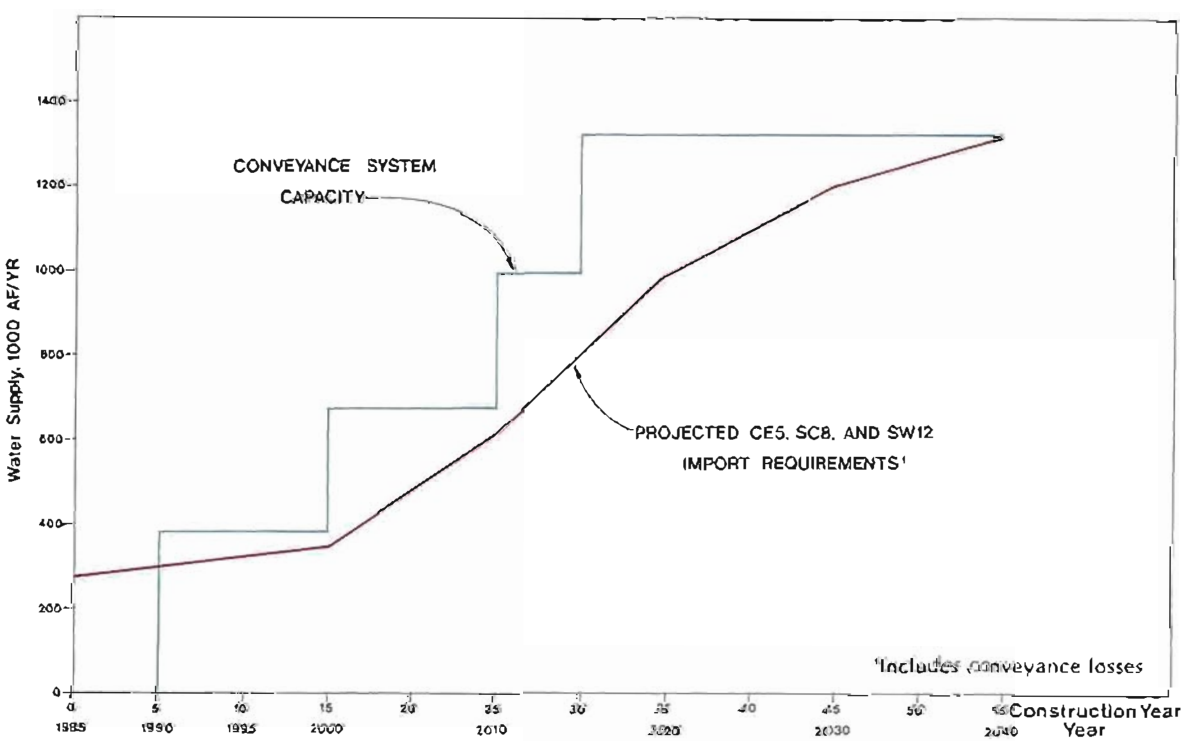


FIGURE 112 SOUTHERN WATER CONVEYANCE SYSTEM CONSTRUCTION STAGING

FIGURE 113 SOUTHERN WATER CONVEYANCE SYSTEM ALLOCATION OF TERMINAL RESERVOIRS[1] (In 1,000 Af/Yr)

PLANNING REGION	West Elm Creek and Draper M&I	West Elm Creek and Draper Irrigation	Verden M&I	Verden Irrigation	Fort Cobb M&I	Fort Cobb Irrigation	Foss M&I	Foss Irrigation	Tom Steed M&I	Tom Steed Irrigation	Altus M&I	Altus Irrigation	Mangum M&I	Mangum Irrigation	Snyder M&I	Snyder Irrigation	Total
County																	
CENTRAL																	
Canadian	48.0	0															48.0
Cleveland	90.4	0															90.4
McClain	36.1	0															36.1
Oklahoma	285.6	0															285.6
Pottawatomie	26.9	0															26.9
Subtotal	487.0	0															487.0
SOUTH CENTRAL																	
Grady[2]			18.5	17.0													35.5
Subtotal			18.5	17.0													35.5
SOUTHWEST																	
Beckham							5.0	0									5.0
Caddo					41.2	10.6											51.8
Comanche															10.6	0	10.6
Cotton[3]																	
Custer							0	10.6									10.6
Greer													1.9	42.5			44.4
Harmon													0	60.0			60.0
Jackson									9.8	62.6	0	65.0			0	91.4	228.8
Kiowa					0	48.2	2.1	45.3	1.9	27.7							125.2
Roger Mills[3]																	
Tillman															0	224.6	224.6
Washita							1.3	36.6									37.9
Subtotal					41.2	58.8	8.4	92.5	11.7	90.3	0	65.0	1.9	102.5	10.6	316.0	798.9
TOTAL	487.0		35.5		100.0		100.9		102.0		65.0		104.4		326.6		1,321.4[4]

[1]Maximum import capabilities.
[2]Only county in South Central Planning Region served by conveyance system.
[3]Not served by conveyance system.
[4]Total reflects firm yield of reservoirs as well as import supplies.

plants and three reservoir-type pumping plants would be required.

Terminal storage in southwestern Oklahoma would be provided by seven reservoirs, four of which are existing, and three proposed. (See Figure 97.) Altus Dam would require modification to accommodate an additional 70,000 acre-feet of conservation storage, a modification presently under study as part of the Safety of Dams Act. No other existing dams in the conveyance system would require modification. Grady County would be the only county in the South Central Planing Region to receive water from the proposed conveyance system. The proposed Verden Reservoir in the Southwest Planning Region would provide Grady County with 35,500 acre-feet of municipal, industrial and irrigation water per year, requiring an average conveyance of 28,000 acre-feet per year.

Ten of the 12 counties in the Southwest Planning Region would receive import water. Fort Cobb Reservoir would supply 100,000 acre-feet of water per year to Caddo and Kiowa Counties for municipal, industrial and irrigation purposes. Foss Reservoir would be operated in conjunction with the Carnegie Diversion Dam to supply Beckham, Custer, Kiowa and Washita Counties with 100,900 acre-feet of water per year. Tom Steed Reservoir, on the North Fork of the Red River, would yield 102,000 acre-feet of water per year to Jackson and Kiowa Counties, primarily for irrigation, and Altus Reservoir would supply Jackson County with an additional 60,000 acre-feet of water per year for irrigation. The two proposed reservoirs in the Southwest Planning Region, Mangum and Snyder, would provide 431,000 acre-feet annually to Comanche, Greer, Harmon, Jackson and Tillman Counties.

The southern water conveyance system in its entirety would supply approximately 1.3 million acre-feet of water annually to meet the future water deficits of central and southwestern Oklahoma. Figure 113 shows the counties served by the southern water conveyance system, their sources of supply and amounts of import water provided.

STAGING

Construction of the southern water conveyance system would require 30 years, staged in four segments to minimize the unit cost of water supplied. (See Figure112.) The initial stage would include development of a portion of the source component in southeastern Oklahoma, construction of the main aqueduct to central Oklahoma and development of the first phase of the western Oklahoma canal. The second stage would consist of an extension of the western canal to southwestern Oklahoma, as well as an increase in source supplies. The third and fourth stages would both include augmentation up to ultimate capacity of the source component in southeastern Oklahoma.

The first stage, requiring an estimated six years to complete, would include development of the eastern leg of the southern system, or one of the alternatives considered in the Corps of Engineers' Central Oklahoma Project (COP) investigations, and construction of the initial phase of the western canal to the main aqueduct. To develop the source component, the authorized Tuskahoma Reservoir and the Moyers Dam, Pumping Plant and Canal would be built, along with the main canal to Lake Stanley Draper. The proposed West Elm Creek Lake would also be constructed to serve as a terminal reservoir in central Oklahoma. The initial stage of the Wayne Pipeline would be built, then tied into the segment of the western canal from Wayne to Fort Cobb Reservoir. The proposed Verden Reservoir in Grady County would be required as terminal storage. Upon completion of the first stage, capacity of the system would be approximately 380,000 acre-feet per year, utilizing water from Clayton and Tuskahoma Reservoirs.

The second stage, scheduled for completion approximately 10 years later, would include extending the western conveyance canal to southwestern Oklahoma and construction of proposed Snyder and Mangum Reservoirs to provide terminal storage for imported water. In southeastern Oklahoma, pumping plants and pipelines tying Hugo Reservoir into the system as a major water supply source would be added, increasing the system's capacity to 672,000 acre-feet annually. By the seventh year of the second stage (or thirteenth year of the total construction period) sufficient water supply facilities would be completed so that all counties served by the conveyance system would have adequate water to meet their import requirements.

During the third stage of development, the capacity of the source component would be increased through the construction of authorized Boswell Lake in Choctaw County and addition of pumps and pipeline to the Wayne Pipeline to increase the amount of water supplied to south central and southwestern Oklahoma. Capacity at the end of the third stage would be approximately one million acre-feet annually. Construction of the third stage would require about two years with completion scheduled for the twenty-fifth year after the start of construction.

The fourth and final stage of the southern system would increase the capacity of the source component to its ultimate capacity by adding additional pumps and conduits to the sources. At the end of this stage, about the thirtieth year of the construction period, ultimate capacity of 1,320,000 acre-feet per year would be achieved.

COSTS

Cost estimates for the southern water conveyance system indicate a total construction cost of approximately $2.5 billion for proposed new reservoirs, conveyance canals, water supply storage in existing and authorized federal reservoirs and pertinent distribution facilities. The average annual equivalent cost would be approximately $190 million, which includes $53 million for annual OMR&E costs and $1.3 million for mitigation/compensation. A major portion of these costs consists of energy/pumping costs calculated at a 30-mil power rate with annual requirements estimated at 2.4 billion KWH. The construction cost includes $120 million for new dams and reservoirs, $105 million for water supply storage in existing and authorized reservoirs, $1.425 billion for conveyance facilities, $765 million for ir-

FIGURE 114 SOUTHERN WATER CONVEYANCE SYSTEM SUMMARY OF PROJECT COSTS[1] (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COSTS[3]
SOURCE COMPONENT (includes conveyance to Central Region)			
Conveyance Facilities	$ 868,000	$ 19,500	$ 75,000
Reservoir Storage	104,000	—	3,400
SUBTOTAL	$ 972,000	$ 19,500	$ 78,400
DELIVERY COMPONENT (Wayne turnout to South Central and Southwest Regions)			
Conveyance Facilities	$ 557,000	$ 28,090	$ 54,915
Existing Reservoir (Altus modification)	19,000	25	735
Proposed Reservoirs (Verden, Snyder and Mangum)	102,000	500	4,780
Irrigation Distribution	765,000	4,220	45,360
M & I Distribution	75,000	560	4,410
SUBTOTAL	$1,518,000	$ 33,395	$110,200
MITIGATION/COMPENSATION COSTS	$ 18,000	$ 100	$ 1,300
TOTAL	$2,508,000	$ 52,995	$189,900

[1]Based on January 1978 prices.
[2]Energy computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E.

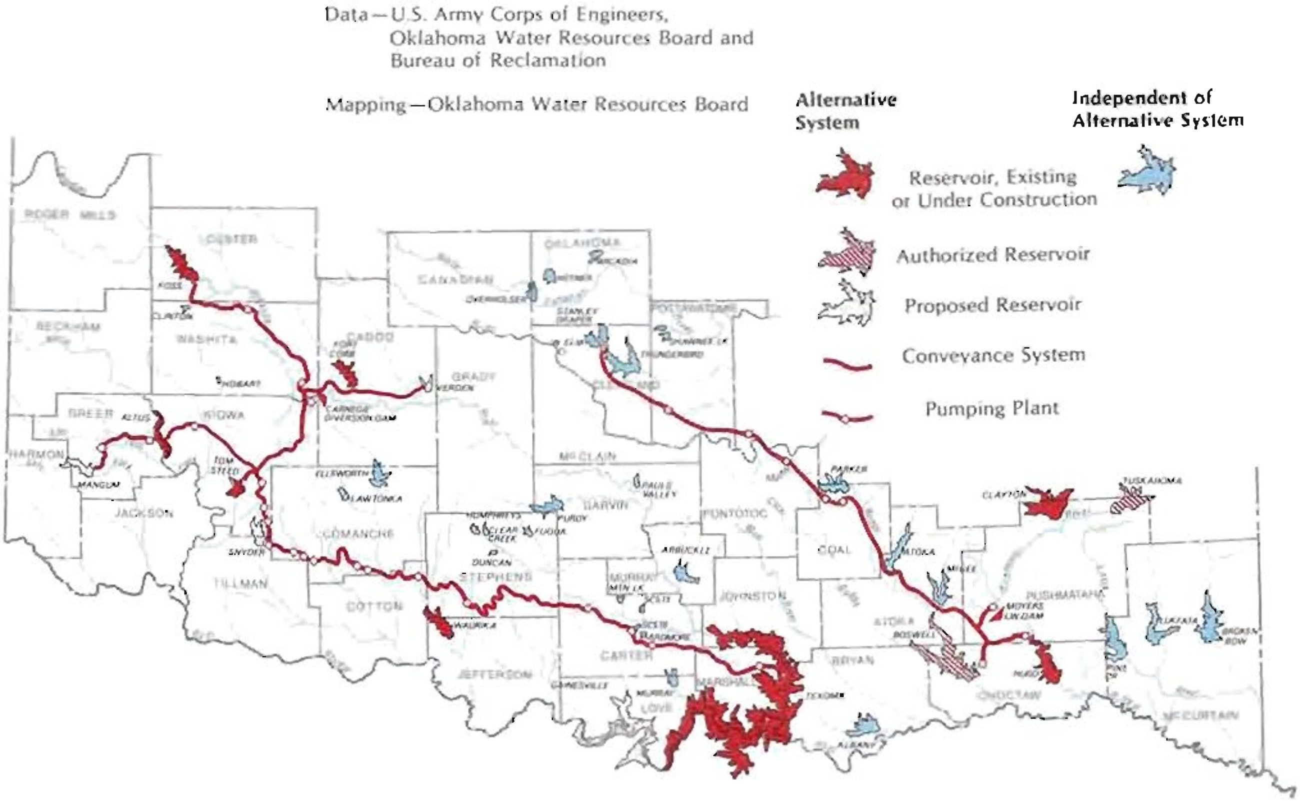


FIGURE 115 RED RIVER ALTERNATIVE WITH CHLORIDE CONTROL

rigation transmission lines, $75 million for municipal and industrial delivery facilities and $18 million for mitigation/compensation.

Figure 114 shows the estimated costs of source and delivery components of the southern system as well as mitigation/compensation costs. The source component, which includes the cost of the canal to central Oklahoma, is estimated to cost $972 million. The delivery component is estimated to cost $1.5 billion.

BENEFITS

Direct benefits accruing from the southern water conveyance system are estimated at $64.6 million, with $8 million attributable to irrigation and $56.6 million to municipal and industrial benefits.

BENEFIT-COST ANALYSIS

A comparison of annual benefits ($64.6 million) with costs ($190 million) indicates that the southern water conveyance system has a benefit-cost ratio of .34:1. Under federal planning guidelines, such a ratio renders a project infeasible and precludes its construction. Substantial indirect economic impacts which would occur, but which are not included in the analysis, would also need to considered prior to any final feasibility determination.

Red River Alternative With Chloride Control

The lack of economic feasibility under federal criteria for the irrigation component of the southern water conveyance system prompted a cursory assessment of an alternative utilizing water sources closer to the area of use. This alternative basically separates the proposed southern water conveyance system into two independent systems. One would furnish municipal, industrial and irrigation water to south central and southwestern Oklahoma from the Red River in south central Oklahoma, while the other would follow the same alignment as that previously discussed from southeastern to central Oklahoma.

By so doing, further planning of the municipal and indusrial water conveyance elements from southeastern Oklahoma to central Oklahoma possibly could proceed without reliance on transfers westward.

Preliminary studies for the Red River Basin Chloride Control Projects indicate that the Red River possesses the potential to be a suitable source of water after completion of the authorized chloride control projects located upstream. Natural brine springs and salt flats in the river's upper reaches currently render the water unfit for any beneficial purpose. However, control of those chloride emission zones would improve the quality of the water and make it suitable for most beneficial purposes.

Figure 115 shows the conveyance route of this alternative. Although containing a much different alignment than the southwestern leg of the proposed southern water conveyance system, this alternative would utilize the same existing and proposed terminal reservoirs in southwestern Oklahoma.

Lake Texoma and the potential Gainesville Lake would operate in tandem to provide the quantities of water required by southwestern Oklahoma. The alignment of the system to central Oklahoma would be the same as currently proposed in the southern conveyance system.

Utilization of Texoma and Gainesville Lakes as water sources for south central and southwestern Oklahoma is contingent upon several factors, among which are: (1) the chloride control projects would have to be completed and operational for the water in Lake Texoma to be of quality suitable for use; (2) Congressional reallocation of hydropower and inactive storage in the reservoir to water supply storage would be necessary; (3) storage allocation provisions of the Red River Compact would have to be met; (4) an assessment of a reduction in downstream releases would be required; and (5) further studies to assess the feasibility of the proposed Gainesville Lake would be necessary.

The Red River is an interstate stream subject to provisions of the compact between Oklahoma, Texas, Arkansas and Louisiana. Since the agreement requires Texas and Oklahoma to divide equally the storage from existing and proposed reservoirs on the main stem of the river, it would be necessary to coordinate this alternative with Texas water officials during early stages of additional planning.

Storage providing a yield of 857,600 acre-feet per year to Oklahoma would be required to meet southwestern and south central Oklahoma's projected deficits. The dependable yield from Texoma, assuming all the hydropower and inactive storage could be converted to water supply, would be about one million acre-feet annually, half of which or 500,000 acre-feet per year would be available for use in Oklahoma. Additional storage would be needed to offset increased sedimentation in Texoma and develop the supply necessary to meet the import requirements of southwestern Oklahoma during the planning period. Preliminary studies indicate that the potential Gainesville dam site, located about 70 miles upstream from Dension Dam, could be developed to operate in conjunction with Texoma to provide sufficient water of suitable quality to meet the import needs of southwestern Oklahoma. Gainesville, like Texoma would be subject to the terms of the Red River Compact and although no negotiations have as yet been initiated with Texas officials, this alternative would appear to be in accord with the State of Texas' water policy.

The conversion of Lake Texoma hydropower storage to water supply storage would eliminate all power production, and reduced downstream releases could have adverse impacts on fish and wildlife habitat, as well as potential navigation activity. The loss of the energy produced at Lake Texoma would have to be compensated for by either paying for the hydropower benefits foregone, or replacing the energy lost with energy produced from steam electric generating facilities. However, "scalping" operations on Lake Texoma and Gainesville similar to those employed in the northern water conveyance system could possibly provide sufficient quantities of water without loss of the hydroelectric power capability. More comprehensive studies will be necessary to address these issues and to determine the potential adverse environmental effects.

ADVANTAGES OF REGIONAL WATER DEVELOPMENT

Apparent advantages of the Red River alternative are multifaceted. Water obtained nearer the area of use would not only substantially reduce reliance on transfers from southeastern Oklahoma, but might result in cost savings. In addition, with two independent systems each conveyance element could be evaluated on its own merits. Preliminary studies by the Corps indicate that a plan for conveyance of surplus water from southeastern to central Oklahoma for municipal and industrial use may presently be economically feasible and removal of the irrigation features could facilitate the planning for the Central Oklahoma Project (COP).

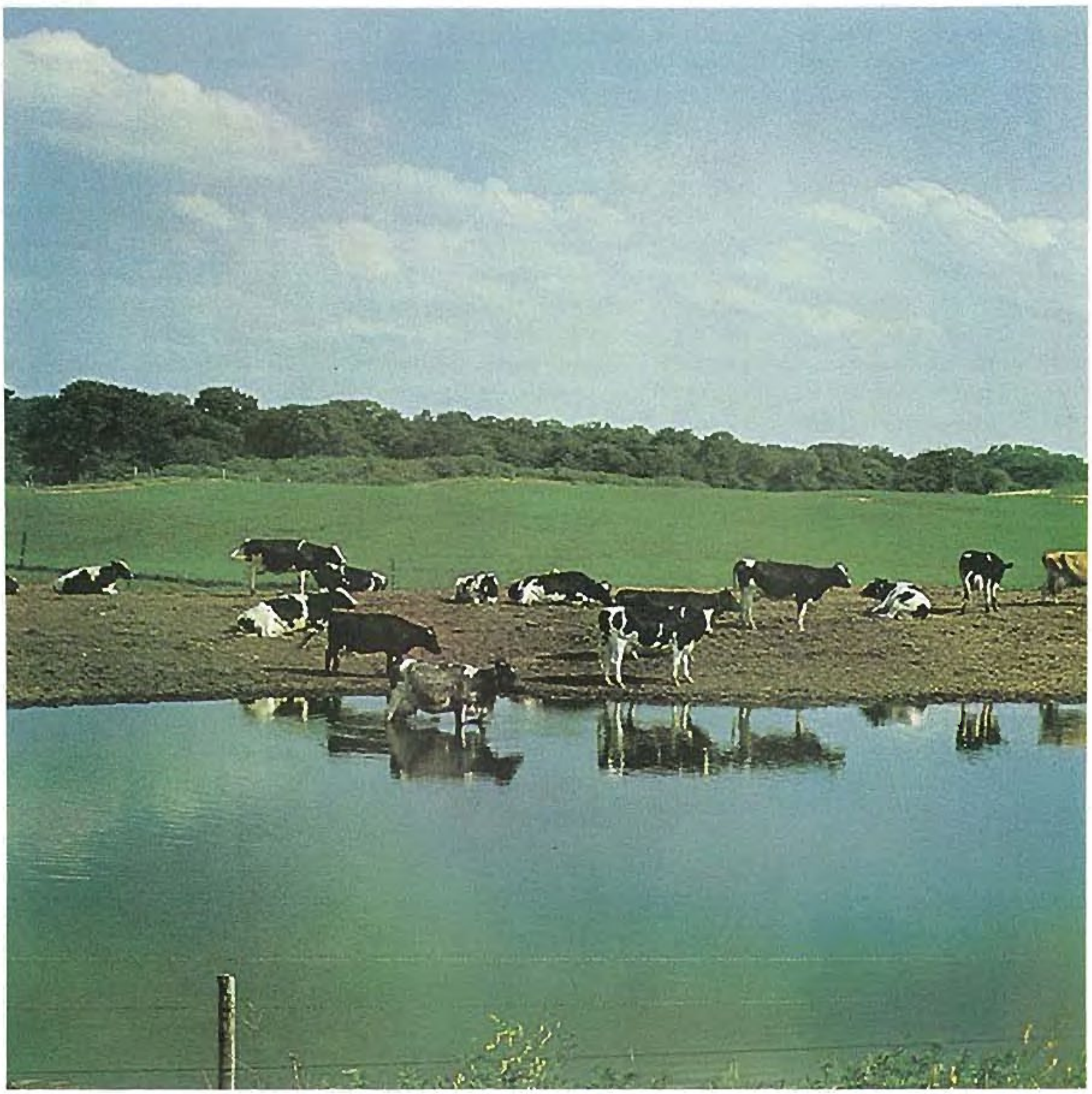
Although the Corps of Engineers' COP study is currently inactive, earlier COP studies formulated alternatives based on both 50 and 100-year planning horizons.

If a 50-year plan of development for central Oklahoma were implemented, the conveyance system would be designed for a much smaller capacity than the proposed system and probably would not require construction of the authorized Boswell Reservoir as a source of supply. In addition, utilization of underground pipelines rather than an open canal would probably be more cost-effective for a 50-year plan. If a 100-year plan of development were chosen, the conveyance system would be similar to the canal proposed in the southern system, but probably would be designed for a slightly smaller capacity and still require construction of Boswell Reservoir.

Projections indicate that existing water supplies for central Oklahoma, including Arcadia and McGee Creek Lakes currently under construction, will satisfy the area's water needs only until the mid-1990's. With the lead time necessary for planning, design and construction, it appears unlikely even if work resumed today, that the COP could be completed in time to forestall water shortages in central Oklahoma. Additional planning, authorization, design and construction of COP facilities would require at least 15 years, but considering the project's magnitude, 20 years would probably be a more realistic time period.

In the absence of a major water conveyance plan, it is anticipated that communities would independently implement smaller water import plans of a piecemeal and short-range nature. Such uncoordinated development would undoubtedly result in substantially higher costs than a regional conveyance system such as COP, which takes advantage of economies of scale.

CHAPTER VII
EASTERN OKLAHOMA WATER SUPPLY STUDIES



PURPOSE

The studies discussed in this chapter incorporate in the plan the desires expressed by several eastern Oklahoma legislators, economic development organizations and segments of the general public regarding water resource development and serve to reassure those interests that any system proposed to convey water to the west would utilize only water exceeding the future water needs of eastern Oklahoma. The water supply system presented here for eastern Oklahoma is an expansion of the Regional Plans of Development included in the "Regional Analyses" (Chapter V.)

BACKGROUND

These studies were conducted as a response to criticism voiced following publication of Phase I of the Oklahoma Comprehensive Water Plan in 1975. Some eastern Oklahomans stated that the water requirement projections underestimated their area's potential for growth and industrial development. Concern was expressed that water necessary to meet the future needs of the area might be transported to other areas of the state, and thereby preclude future growth and economic development of eastern Oklahoma.

In early 1976, legislators from southeastern Oklahoma, substate planning district representatives, and members of the Planning Committee met at the State Capitol to discuss perceived shortcomings of Phase I of the Oklahoma Comprehensive Water Plan. At the meeting it was agreed that additional studies would be conducted in the Southeast Planning Region. This approach was later extended to the northeast 26 counties in conjunction with the Board's planning efforts in the northern 44 counties.

STUDY AREA

The 34 easternmost counties were chosen for their study area, which include the Board's Southeast, East Central and Northeast Planning Regions, plus Lincoln and Pottawatomie Counties. The study area includes the following substate planning districts: Eastern Oklahoma Development District (EODD), Kiamichi Economic Development District of Oklahoma (KEDDO), North Eastern Counties of Oklahoma (NECO), Indian Nations Council of Governments (INCOG), Central Oklahoma Economic Development District (COEDD), excluding Payne and Pawnee Counties, and the five easternmost counties of Southern Oklahoma Development Association (SODA).

COORDINATION

Coordination throughout the study was accomplished through meetings sponsored by the following substate planning districts: SODA, KEDDO, EODD, NECO and COEDD, and the Economic Resource Development Association (ERDA). The Economic Resource Development Association is an organization with a membership from 24 counties, formed in 1975 to promote and assist in the development of the economic, social and industrial potential in southeastern Oklahoma.

Population and water requirement projections for the Eastern Oklahoma Water Supply System are based upon meetings conducted by the Oklahoma Water Resources Board, the Corps of Engineers and the substate planning districts. Projections for the Indian Nations Council of Governments (INCOG) area are those developed in the Tulsa Urban Study by the Corps of Engineers, in coordination with INCOG and other study participants. Following finalization of these projections, alternative water supply plans were developed and submitted to ERDA and the substate planning districts for their review. A system was selected from the alternatives and is included as part of the Oklahoma Comprehensive Water Plan.

Full coordination and development of the water supply system for eastern Oklahoma are incomplete, pending agreement on details of the selected plan by EODD's Board of Directors. These details concern the reallocation of hydropower and inactive storage in Tenkiller Lake to water supply storage. Several EODD Board members were concerned that adverse impacts might be felt by local recreation interests during the irrigation season if increased diversions of irrigation water significantly lowered Tenkiller's water level. They questioned whether the economic benefits accruing from the proposed irrigation usage would exceed those realized from established recreation activities in the area and requested the preparation of a comparative analysis to assess relative recreation and irrigation benefits. If recreation benefits did indeed exceed irrigation benefits, they believed an alternative water supply source should be identified and included in the plan rather than utilizing Tenkiller for irrigation purposes.

The Tenkiller Lake restudy currently underway by the Corps of Engineers will be completed in 1982, and as it progresses the issues raised by EODD will be considered for inclusion in future revisions of the Oklahoma Comprehensive Water Plan. Appropriate public and professional participation in this study will ensure that the most economical and beneficial uses of the lake will be identified.

WATER SUPPLY SOURCES

Both stream water and ground water were considered as sources of supply in the study.

Stream water resources include existing, under construction, authorized and potential lakes. The Arkansas River below Keystone Lake was assumed to be usable as a water supply source, upon the assumption that the Arkansas River Basin Chloride Control Projects would be operational and economically feasible. Waters of the Arkansas could be utilized even without chloride control, but water of suitable quality would be available less frequently and at a greater cost. Utilization of offstream regulating reservoirs was considered necessary to provide a

FIGURE 116 EASTERN OKLAHOMA STUDY AREA YEAR 2040 PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

PLANNING REGION County	M & I[1]	IRRIGATION	TOTAL
SOUTHEAST			
Atoka	42.1	94.1	136.2
Bryan	151.5	268.8	420.3
Choctaw	27.2	169.1	196.3
Coal	54.7	39.9	94.6
Johnston	32.0	12.1	44.1
McCurtain	109.2	178.1	287.3
Pontotoc	71.8	183.2	255.0
Pushmataha	21.7	65.0	86.7
Subtotal	510.2	1,010.3	1,520.5
EAST CENTRAL			
Haskell	18.6	89.2	107.8
Hughes	10.1	6.9	17.0
Latimer	7.0	31.3	38.3
LeFlore	30.3	88.1	118.4
McIntosh	17.2	114.3	131.5
Okfuskee	12.7	2.9	15.6
Pittsburg	37.0	81.6	118.6
Seminole	240.4	2.6	243.0
Sequoyah	52.9	58.0	110.9
Subtotal	426.2	474.9	901.1
NORTHEAST			
Adair	17.0	24.3	41.3
Cherokee	53.7	39.6	93.3
Craig	12.1	4.6	16.7
Creek	31.9	5.6	37.5
Delaware	26.8	2.7	29.5
Mayes	96.5	3.5	100.0
Muskogee	84.9	180.8	265.7
Nowata	12.4	2.7	15.1
Okmulgee	51.8	105.0	156.8
Osage	9.0	18.2	27.2
Ottawa	40.1	1.6	41.7
Rogers	180.9	2.3	183.2
Tulsa	400.0	5.6	405.6
Wagoner	70.0	116.5	187.5
Washington	37.7	4.3	42.0
Subtotal	1,124.8	517.3	1,642.1
LINCOLN COUNTY[2]	11.3	17.4	28.7
POTTAWATOMIE COUNTY[3]	48.1	32.0	80.1
TOTAL	2,120.6	2,051.9	4,172.5

[1]Includes cooling water for power generation.
[2]Located in North Central Planning Region.
[3]Located in Central Planning Region.

dependable source of water supply from the Arkansas.

Major sources of ground water in the study area were identified as the Vamoosa, Roubidoux, Arbuckle and Antlers Sandstone ground water basins and various alluvium and terrace deposits. A minimum well yield of 200 gallons per minute (gpm) was assumed necessary before ground water was considered for municipal and industrial purposes, and a minimum 150 gpm yield was assumed necessary for irrigation purposes.

PROJECTED WATER REQUIREMENTS

Projections of water requirements, based on data provided by the substate planning districts and ERDA, totaled 4.2 million acre-feet annually by the year 2040. This compares with approximately two million acre-feet per year forecast by the Oklahoma Comprehensive Water Plan Planning Committee and used in developing the regional water development plans discussed in Chapter V. The major difference in the projections is the extensive amount of irrigation forecast by the substate districts and ERDA, which is not projected by the Planning Committee. These projections for the year 2040 are shown by planning region and county in Figure 116 .

Although developed individually, utility demands (consumptive water requirements for cooling at thermal electric generating plants) and industrial demands were combined with municipal demands into a single municipal and industrial demand component (M&I).

DEMAND CENTERS

When considering each municipality, rural water district, industrial complex, or utility demand area appropriate for inclusion in projections of future water requirements, it became apparent that many were components of an areawide system. Many towns and communities were discovered to be acquiring water from other and often larger entities via direct lines or a system of rural water districts. In considering the types of systems that would be serving eastern Oklahoma in the future, it became apparent that a network of rural water districts would probably be the most appropriate distribution system. In most cases, water furnished by rural water districts is treated water from a centralized facility. Since this study intended to develop alternative plans for the conveyance of water from sources to treatment facilities, with the exclusion of treatment and distribution facilities, it was difficult to determine whether or not some rural systems qualified as conveyance or distribution systems. The concept of providing individual treatment facilities for each entity would lead to a very inefficient and high cost solution, thus it was considered appropriate to identify certain demand centers within each county as terminal locations for water conveyance facilities.

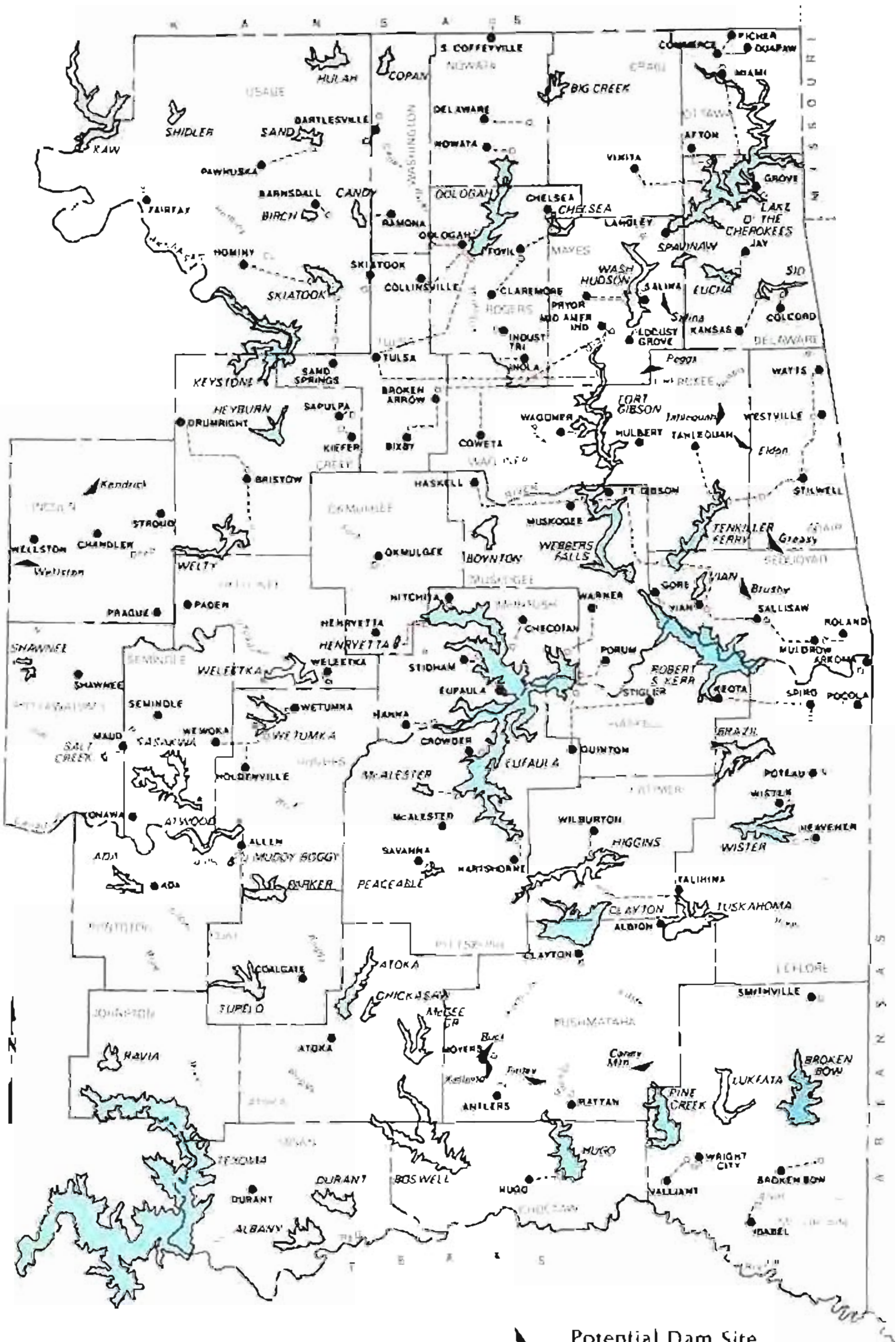
A demand center was identified as a city, a group of communities using a common water supply source, or an industrial or utility demand area having a projected water requirement of 1.0 mgd or greater by the year 2040. Exceptions were entities which were geographically isolated or located closer to a source than to a demand center.

Some demand centers possessed specific characteristics which made them unique. The Mid-American Industrial Complex in Mayes County, the source of treated water for the City of Pryor, was treated as a single demand center located at Pryor. The industrial triangle in southern Rogers County was also considered an industrial water demand center.

Although no future power generating plant sites were identified by utility company officials, a substantially increased utility demand was forecast for Seminole and Okfuskee Counties, the sites of existing plants. Therefore, utility demand centers were established near potential sources, under the assumption that when the need for additional power plants materializes, they would locate near available water sources instead of conveying water to the plant.

Irrigation demands were developed on a countywide basis and no specific demand centers or terminal points were identified. It was assumed that irrigation demands would first be met by utilizing ground water where it is available. Where ground water was not a viable source, stream water sources were considered, and the costs of irrigation water from stream water sources were included in the cost estimates. No specific plans were developed for the movement of irrigation water from sources or terminal points within a county to specific demand areas. If the supply was a stream water source outside the county, the cost of a transmission system to move the water into the county was included in the cost estimates.

FIGURE 117 EASTERN OKLAHOMA MUNICIPAL AND INDUSTRIAL WATER SUPPLY SYSTEM



Reservoir, Existing or Under Construction

Authorized Reservoir

Proposed Reservoir

Potential Dam Site

Water Supply Source

Utility Water Supply Source

Distribution Facility

Demand Center

Data—U.S. Army Corps of Engineers
Mapping—Oklahoma Water Resources Board

EASTERN OKLAHOMA WATER SUPPLY SYSTEM

The Eastern Oklahoma Water Supply System would require development of both ground water and stream water resources beyond that proposed in the Regional Plans of Development in order to meet the higher future water needs forecast by local planners. Sources of supply include existing, authorized and proposed reservoirs, the Arkansas River and additional ground water resources. The concept underlying the system presented here is an expansion of the Regional Plans of Development proposed for the Northeast, East Central and South Central Planning Regions. Costs of the Eastern Oklahoma Water Supply System include costs of the proposed Regional Plans of Development plus costs of additional development to meet the higher projected needs.

Municipal and Industrial Water Supply System

Figure 117 illustrated the water supply system proposed to meet the municipal and industrial water demands forecast by the local interests. As indicated in Figure , 10 reservoirs in addition to those proposed in the "Regional Analyses" would be required to supply 328,100 acre-feet of municipal and industrial water per year to the 34-county area. These reservoirs are: Big Creek and Chelsea in the Northeast Planning Region; Brazil, Higgins, and Peacable in the East Central Planning Region; and Ada, Chickasaw, Durant, Lukfata (authorized) and Ravia in the Southeast Planning Region.

Additional ground water supplies would also have to be developed to meet a portion of the municipal and industrial water needs. Approximately 42,000 acre-feet per year of additional ground water would supply Lincoln, Okfuskee, Pottawatomie and Seminole Counties.

The area's remaining municipal and industrial water demands would be met by water from existing reservoirs and those proposed in the "Regional Analyses". A greater portion of the yield from these sources would be utilized to meet the higher projected requirements in the Eastern Oklahoma Water Supply System than in the local plans proposed in the "Regional Analyses".

Municipal and industrial distribution facilities from the water sources to appropriate demand centers are also shown in Figure 117. The total municipal and industrial water demand for the three planning regions plus Lincoln and Pottawatomie Counties is projected to be approximately 2.1 million acre-feet by 2040. Figures 118, 119, 121 and 122 present the 34 counties in the study area along with their projected 2040 municipal and industrial water demands and proposed sources.

Irrigation Water Supply System

Figure 123 illustrates the irrigation component of the Eastern Oklahoma Water Supply System. This system would require the construction of one additional reservoir, Boynton Lake in Muskogee County, to serve as off-stream regulating storage for water diverted from the Arkansas River. Upon reallocation of storage, several of the existing and proposed reservoirs would be utilized for irrigation purposes, along with six of the 10 new reservoirs previously proposed. Where downstream releases would be made, the water would be diverted at the points shown in Figure 123. Ground water and SCS Lakes would supply most of the irrigation water along with water conveyed from major reservoirs, while Coal, Nowata and Latimer Counties would rely solely on major reservoirs for irrigation water.

Distribution facilities are presented for irrigation water supplied by reservoirs in adjacent counties. In the 34-county area, total irrigation requirements projected for the year 2040 are approximately two million acre-feet per year to irrigate two million acres.

Figures 118, 119, 121 and 122 show 2040 irrigation water requirements and proposed sources.

Costs

Preliminary cost estimated for the Eastern Oklahma Water Supply System are presented in Figure 120 . Construction of the municipal and industrial component would cost approximately $950 million, while the cost of the irrigation system is estimated at nearly $2 billion. The

FIGURE 118 EASTERN OKLAHOMA WATER SUPPLY SYSTEM YEAR 2040 SUPPLY AND DEMAND ANALYSIS LINCOLN AND POTTAWATOMIE COUNTIES (In 1,000 Af/Yr)

Source	Pottawatomie[1]	Lincoln[2]
M & I Component		
Ground Water & SCS & Municipal Lakes	21.2	11.3
Southern Conveyance System	26.9	—
M & I Supply	48.1	11.3
Irrigation Component		
Ground Water & SCS Lakes	32.0	17.4
Irrigation Supply	32.0	17.4
TOTAL LOCAL SUPPLY	80.1	28.7
2040 DEMAND	80.1	28.7

[1]Located in Central Planning Region.

[2]Located in North Central Planning Region.

FIGURE 119 EASTERN OKLAHOMA WATER SUPPLY SYSTEM YEAR 2040 SUPPLY AND DEMAND ANALYSIS NORTHEAST PLANNING REGION (In 1,000 Af/Yr)

Source	Adair	Cherokee	Craig	Creek	Delaware	Mayes	Muskogee	Nowata	Okmulgee	Osage	Ottawa	Rogers	Tulsa	Wagoner	Washington	Total
Municipal and Industrial Component[1]																
Ground Water & SCS & Municipal Lakes[2]	—	22.4	—	3.5	0.1	—	11.4	4.6	8.9	5.0	—	6.9	153.8	—	11.1	227.7
Birch	—	—	—	—	—	—	—	—	—	1.1	—	5.6	—	—	—	6.7
Candy	—	—	—	—	—	—	—	—	—	0.1	—	7.7	—	—	0.8	8.6
Copan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15.0	15.0
Eufaula	—	—	—	—	—	—	1.9	—	8.0	—	—	—	—	—	—	9.9
Fort Gibson	—	0.7	—	—	—	—	7.8	—	—	—	—	—	165.0	50.3	—	223.8
Grand	—	—	12.1	—	14.2	96.5	—	—	—	—	40.1	—	20.4	19.4	—	202.7
Heyburn	—	—	—	20.7	—	—	—	—	—	—	—	—	—	—	—	20.7
Hulah	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7.7	7.7
Oologah	—	—	—	—	—	—	—	—	—	—	—	101.4	33.7	—	—	135.1
Skiatook	—	—	—	—	—	—	—	—	—	1.2	—	26.4	26.8	—	—	54.4
Tenkiller	17.0	30.6	—	—	—	—	50.7	—	—	—	—	—	—	—	—	98.3
Sand	—	—	—	—	—	—	—	—	—	0.2	—	8.0	—	—	3.1	11.3
Shidler	—	—	—	—	—	—	—	—	—	1.2	—	—	—	—	—	1.2
Big Creek	—	—	—	—	—	—	—	7.6	—	—	—	4.7	—	—	—	12.3
Chelsea	—	—	—	—	—	—	—	—	—	—	—	20.2	—	—	—	20.2
Sid	—	—	—	—	12.2	—	—	—	—	—	—	—	—	—	—	12.2
Welty	—	—	—	7.7	—	—	—	—	34.9	—	—	—	—	—	—	42.6
Adjacent County	—	—	—	—	0.3	—	13.1	0.2	—	0.2	—	—	0.3	0.3	—	14.4
M & I Supply	17.0	53.7	12.1	31.9	26.8	96.5	84.9	12.4	51.8	9.0	40.1	180.9	400.0	70.0	37.7	1,124.8
Irrigation Component																
Ground Water & SCS Lakes	6.6	2.4	0.9	5.6	0.8	0.7	134.6	—	0.2	6.7	1.0	1.3	5.6	116.5	2.2	285.1
Grand	—	—	—	—	—	—	—	—	—	—	0.6	—	—	—	—	0.6
Tenkiller	17.7	37.2	—	—	—	—	46.2	—	—	—	—	—	—	—	—	101.1
Sand	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.1	2.1
Shidler	—	—	—	—	—	—	—	—	—	11.5	—	—	—	—	—	11.5
Big Creek	—	—	3.7	—	—	—	—	2.7	—	—	—	1.0	—	—	—	7.4
Boynton	—	—	—	—	—	—	—	—	104.8	—	—	—	—	—	—	104.8
Chelsea	—	—	—	—	—	1.1	—	—	—	—	—	—	—	—	—	1.1
Sid	—	—	—	—	1.9	1.7	—	—	—	—	—	—	—	—	—	3.6
Irrigation Supply	24.3	39.6	4.6	5.6	2.7	3.5	180.8	2.7	105.0	18.2	1.6	2.3	5.6	116.5	4.3	517.3
TOTAL LOCAL SUPPLY	41.3	93.3	16.7	37.5	29.5	100.0	265.7	15.1	156.8	27.2	41.7	183.2	405.6	187.5	42.0	1,642.1
2040 DEMAND	41.3	93.3	16.7	37.5	29.5	100.0	265.7	15.1	156.8	27.2	41.7	183.2	405.6	187.5	42.0	1,642.1

[1]Includes cooling water for (power) generation.

[2]Includes present use from federal reservoirs and 28,000 acre-feet of wastewater reuse in Tulsa County.

FIGURE 120 EASTERN OKLAHOMA WATER SUPPLY SYSTEM SUMMARY OF COSTS (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E	TOTAL AVERAGE ANNUAL EQUIVALENT COST
M & I Water Supply System			
Water Supply Storage	$ 558,593	$ 7,776	$ 40,213
Ground Water Development	8,247	694	1,183
Water Conveyance Facilities	374,100	19,001	40,812
Terminal Storage	7,800	124	642
Subtotal	$ 948,740	$27,595	$ 82,850
Irrigation Water Supply System			
Water Supply Storage[1]	$ 155,100	$ 1,783	$ 11,374
Ground Water Development	429,760	16,166	29,700
Water Conveyance Facilities	168,100	16,300	28,200
Distribution Facilities	1,242,500	4,129	37,431
Subtotal	$1,995,460	$38,378	$106,705
TOTAL	$2,944,200	$65,973	$189,555

[1]Includes cost of terminal irrigation storage in Southeast Region.

total construction cost for water supply storage, ground water development, water conveyance facilities and distribution facilities could be over $3 million, with an average annual equivalent cost of approximately $190 million. Estimates of annual mitigation/compensation costs have not been included in this analysis.

The first cost of projects contained in the "Regional Analyses" for this area is $870 million. Thus the costs of developing the resources necessary to supply the higher projections are about three-and-a-half times greater than those for the Regional Plans of Development proposed by the Planning Committee. As evident, the irrigation component constitutes the major portion of the overall construction costs due to the greater amount of irrigation forecast in the substate planning projections.

CONTINUED PLANNING EFFORTS

As planning efforts progress toward developing the water resources necessary to meet eastern Oklahoma's future requirements, coordination must be maintained with eastern Oklahoma interests in order to benefit from their firsthand awareness of local problems and needs. As planning studies continue trends may confirm the accuracy of population and water requirement projections developed by local organizations. In such case, the water supply system proposed herein, which is an expansion of the Regional Plan of Development, would be capable of meeting those needs.

As federal, state and local efforts succeed in further development of the industrial potential of eastern Oklahoma, the demand for good quality water will increase. Adequate supplies must remain available to attract new interests and allow for the expansion of established industries.

Although eastern Oklahoma's abundant rainfall has limited the need for irrigation development and eastern Oklahoma soils are shallow and somewhat unresponsive to irrigation due to poor drainage, growing emphasis on agricultural production could possibly stimulate growth of large-scale, project-type irrigation. Preliminary analyses by the Bureau of Reclamation, identical to those used in the economic analysis for the water conveyance systems, indicate that an irrigation system investment would not be justified at current agricultural crop prices. Implementation of such a system could produce a negative per-acre return to the farmer in the Northeast Planning Region because the increased yields from irrigation are not sufficient to offset the higher equipment cost. In all other areas of eastern Oklahoma, the per-acre returns under irrigated conditions would be less than those under dryland conditions. Local irrigation projections appear excessive, but if

FIGURE 121 EASTERN OKLAHOMA WATER SUPPLY SYSTEM YEAR 2040 SUPPLY AND DEMAND ANALYSIS SOUTHEAST PLANNING REGION (In 1,000 Af/Yr)

Source	Atoka	Bryan	Choctaw	Coal	Johnston	McCurtain	Pontotoc	Pushmataha	Total
				Municipal and Industrial Component[1]					
Ground Water & SCS & Municipal Lakes[2]	5.2	1.0	1.0	3.0	13.0	0.9	6.7	—	30.8
Broken Bow	—	—	—	—	—	23.4	—	—	23.4
Hugo	—	—	26.2	—	—	—	—	—	26.2
Pine Creek	—	—	—	—	—	46.7	—	—	46.7
Clayton	—	—	—	—	—	—	—	11.2	11.2
McGee Creek	19.0	—	—	—	—	—	—	—	19.0
Lukfata	—	—	—	—	—	37.0	—	—	37.0
Tuskahoma	—	—	—	—	—	—	—	10.2	10.2
Ada	—	—	—	—	—	—	23.5	—	23.5
Albany	—	35.8	—	—	—	—	—	—	35.8
Chickasaw	17.9	—	—	—	—	—	—	—	17.9
Durant	—	114.7	—	—	—	—	—	—	114.7
Parker	—	—	—	20.5	—	—	26.5	—	47.0
Ravia	—	—	—	—	19.0	—	—	—	19.0
Tupelo	—	—	—	31.2	—	—	15.1	—	46.3
Local Streams	—	—	—	—	—	1.2	—	0.3	1.5
M & I Supply	42.1	151.5	27.2	54.7	32.0	109.2	71.8	21.7	510.2
				Irrigation Component					
Ground Water	94.1	249.1	169.1	—	12.1	178.1	183.2	65.0	950.7
Durant	—	19.7	—	—	—	—	—	—	19.7
Tupelo	—	—	—	39.9	—	—	—	—	39.9
Irrigation Supply	94.1	268.8	169.1	39.9	12.1	178.1	183.2	65.0	1,010.3
TOTAL LOCAL SUPPLY	136.2	420.3	196.3	94.6	44.1	287.3	255.0	86.7	1,520.5
2040 DEMAND	136.2	420.3	196.3	94.6	44.1	287.3	255.0	86.7	1,520.5

[1]Includes cooling water for power generation.

[2]Includes present use from federal reservoirs.

FIGURE 122 EASTERN OKLAHOMA WATER SUPPLY SYSTEM YEAR 2040 SUPPLY AND DEMAND ANALYSIS EAST CENTRAL PLANNING REGION (In 1,000 Af/Yr)

Source	Haskell	Hughes	Latimer	LeFlore	McIntosh	Okfuskee	Pittsburg	Seminole	Sequoyah	Total
				Municipal and Industrial Component[1]						
Ground Water & SCS & Municipal Lakes[2]	1.2	4.4	1.1	4.1	0.7	1.3	12.0	17.1	4.5	46.4
Eufaula	1.2	—	—	—	16.5	—	24.4	—	—	42.1
Tenkiller	—	—	—	—	—	—	—	—	62.8	62.8
Wister	—	—	—	7.8	—	—	—	—	—	7.8
Atwood	—	—	—	—	—	—	—	44.8	—	44.8
Brazil	16.2	—	—	14.7	—	—	—	—	—	30.9
Higgins	—	—	5.9	2.5	—	—	—	—	—	8.4
Peaceable	—	—	—	—	—	—	0.6	—	—	0.6
Sasakwa	—	—	—	—	—	—	—	135.5	—	135.5
Weleetka	—	—	—	—	—	6.1	—	25.1	—	31.2
Welty	—	—	—	—	—	5.0	—	—	—	5.0
Wetumka	—	5.7	—	—	—	0.3	—	17.9	—	23.9
Adjacent County	—	—	—	1.2	—	—	—	—	—	1.2
M & I Supply	18.6	10.1	7.0	30.3	17.2	12.7	37.0	240.4	67.3	440.6
				Irrigation Component						
Ground Water & SCS Lakes	55.7	6.9	—	64.0	0.2	2.9	6.3	2.6	58.0	196.6
Tenkiller	—	—	—	—	114.1	—	—	—	—	114.1
Wister	—	—	14.9	24.1	—	—	—	—	—	39.0
Brazil	33.5	—	—	—	—	—	—	—	—	33.5
Higgins	—	—	16.4	—	—	—	43.6	—	—	60.0
Peaceable	—	—	—	—	—	—	31.7	—	—	31.7
Irrigation Supply	89.2	6.9	31.3	88.1	114.3	2.9	81.6	2.6	58.0	474.9
TOTAL LOCAL SUPPLY	107.8	17.0	38.3	118.4	131.5	15.6	118.6	243.0	125.3	915.5[3]
2040 DEMAND	107.8	17.0	38.3	118.4	131.5	15.6	118.6	243.0	110.9	901.1

[1]Includes cooling water for power generation.

[2]Includes present use from federal reservoirs.

[3]Excess supply used to provide water to adjacent counties in Northeast Planning Region.

widespread irrigation were to become feasible, the irrigation system proposed in this chapter would be capable of meeting those needs.

It should be emphasized that development of the plans proposed in the "Regional Analyses" for eastern Oklahoma would not preclude expansion to the larger system requested by local interests in the future if such expansion were to become warranted.

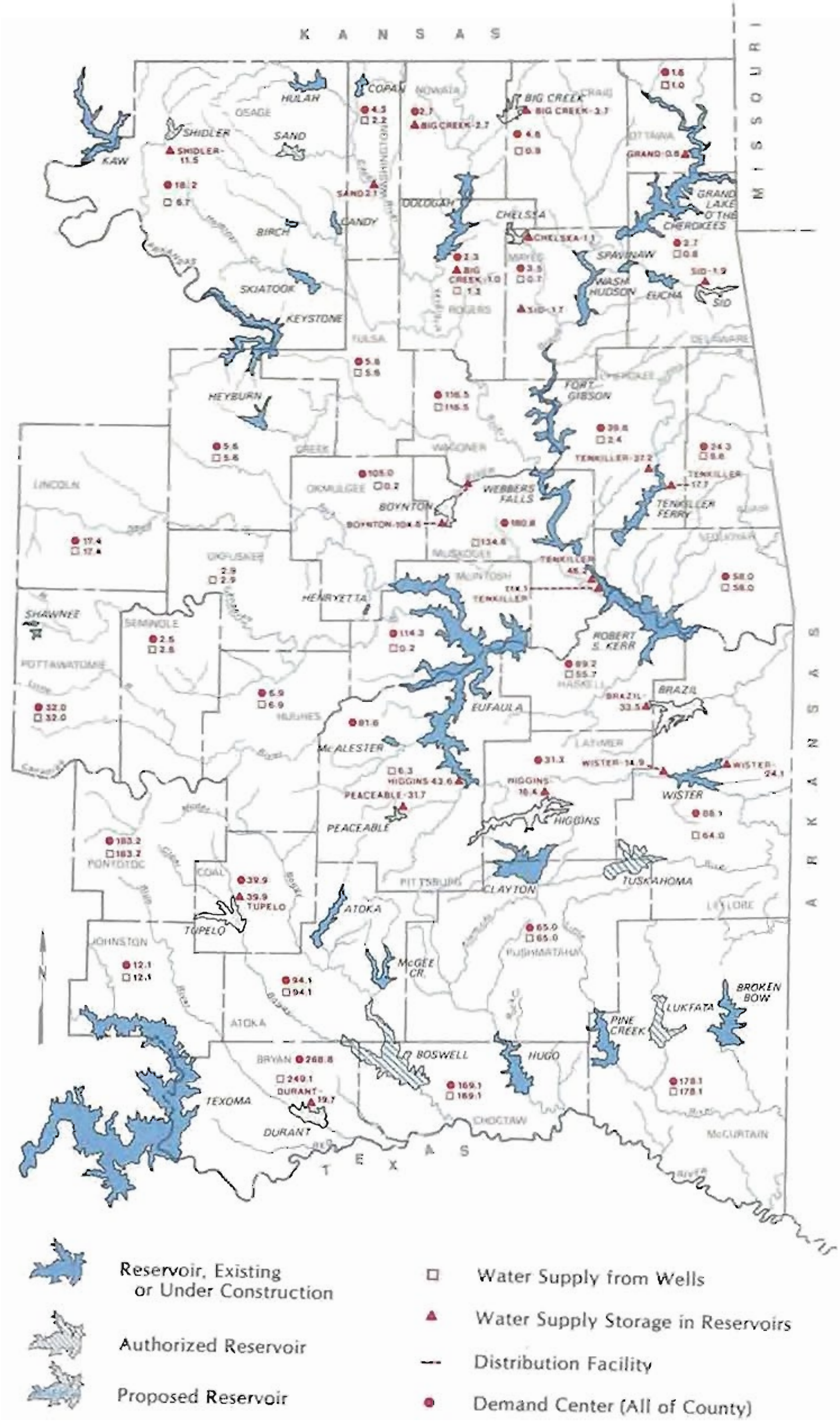
Facilities will have to be constructed to meet the area's increasing water requirements, whether those needs develop as projected by the Planning Committee, eastern Oklahoma organizations or somewhere in between. Therefore, to insure adequate water supplies to eastern Oklahoma residents and industries, the Eastern Oklahoma Water Supply Studies should remain a significant consideration in the evolution of the Oklahoma Comprehensive Water Plan.

SURPLUS WATER AVAILABILITY

Although water development plans for eastern Oklahoma remain at a conceptual level, the studies have progressed sufficiently to show that major water transfers from eastern Oklahoma to central and western areas would not interfere with those plans. As shown in Figure 124, the total yield from potential ground water and stream water development is 10.5 million acre-feet annually. Allowances of 4.3 million acre-feet annually for local use and 2.5 million acre-feet annually for export via the water conveyance system leave a potential surplus exceeding 3.7 million acre-feet per year.

Figure 125 shows the amount of surplus water available based upon the Regional Plans of Development proposed by the Planning Committee. Under these projections, the potential surplus from all sources, after allowances for local use and export, is six million acre-feet annually.

FIGURE 123 EASTERN OKLAHOMA IRRIGATION WATER SUPPLY SYSTEM



Data—Oklahoma Water Resources Board, Bureau of Reclamation and U.S. Army Corps of Engineers

Mapping—Oklahoma Water Resources Board

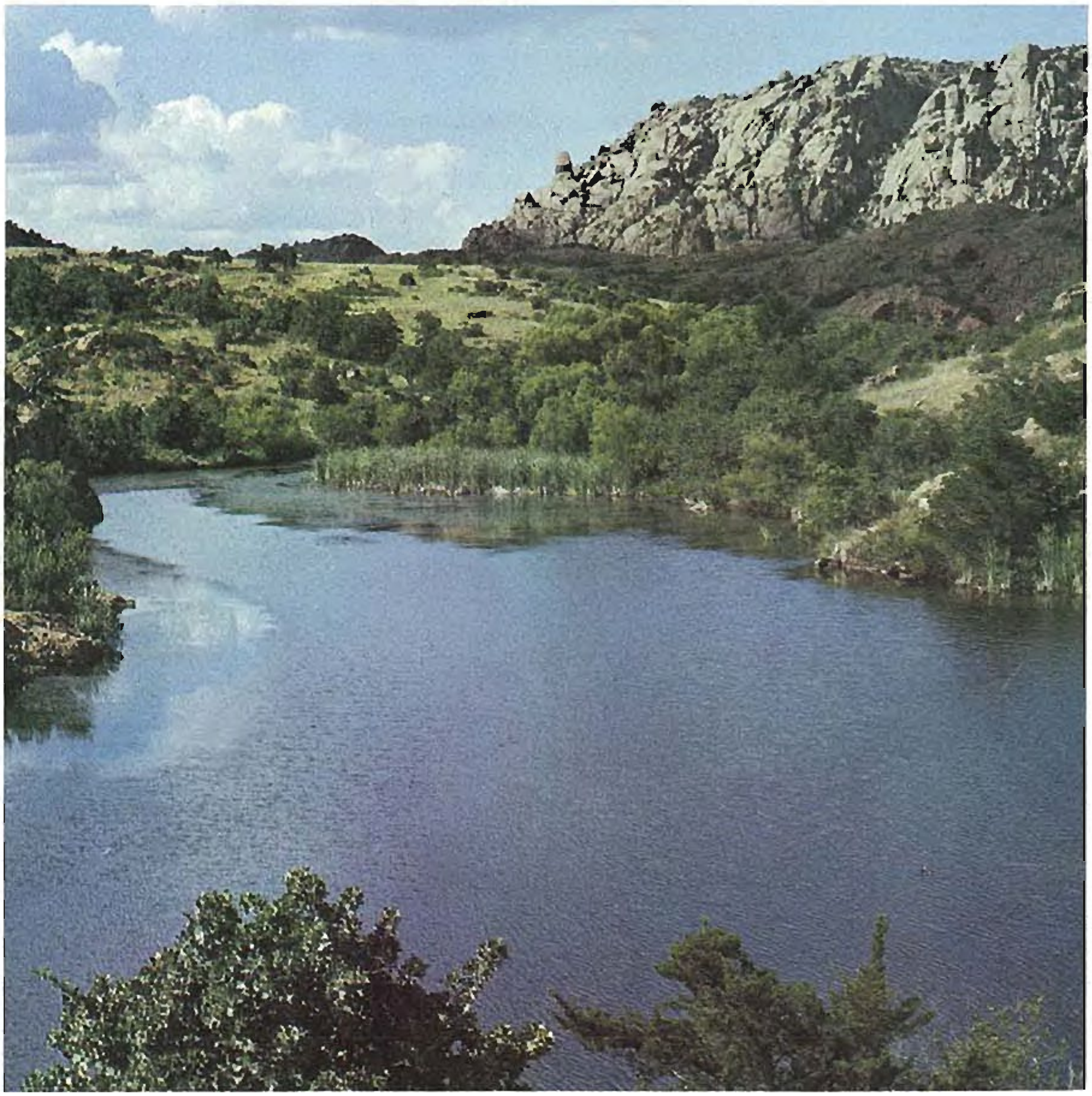
FIGURE 124 EASTERN OKLAHOMA WATER SUPPLY SYSTEM WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Yield	Local Use	Export	Potential Surplus
Ground Water & SCS & Municipal Lakes	3,200	1,780	—	1,420
Major Lakes				
Existing (18)	2,000	1,410	400	190
Authorized (5)	1,050	70	900	80
Proposed (19)	1,190	1,020	—	170
Potential (15)	1,860	—	—	1,860
Subtotal	6,100	2,500	1,300	2,300
Scalping	1,200	—	1,200	—
TOTAL	10,500	4,280	2,500	3,720

FIGURE 125 EASTERN OKLAHOMA WATER AVAILABILITY BASED ON REGIONAL PLANS OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Yield	Local Use	Export	Potential Surplus
Ground Water & SCS & Municipal Lakes	3,200	650	—	2,550
Major Lakes				
Existing (18)	2,000	930	400	670
Authorized (5)	1,050	20	900	130
Proposed (9)	640	400	—	240
Potential (25)	2,410	—	—	2,410
Subtotal	6,100	1,350	1,300	3,450
Scalping	1,200	—	1,200	—
TOTAL	10,500	2,000	2,500	6,000

CHAPTER VIII
CONSIDERATIONS RELATED TO FUTURE DEVELOPMENT



FINANCING WATER RESOURCES DEVELOPMENT

The timely and orderly implementation of the Oklahoma Comprehensive Water Plan will require financial support from federal, state, local and private sources.

As Oklahoma has traditionally relied on the private sector as well as the Federal Government for financing large-scale water projects, so should the state again seek federal funding if it is determined to go forward with the development and construction of a statewide water conveyance system and the Regional Plans of Development. However, federal money is increasingly difficult to secure and generally has stringent controls attached to its use. In addition, the new National Water Policy currently endorses increased cost-sharing by the states.

In light of these national trends, Oklahoma must assume responsibility for providing support at the state and local levels regardless of the nature or extent of federal participation. The state should be prepared to make a substantial investment in a timely fashion if adverse economic consequences are to be avoided. Local interests must make a commitment for their share before Congress can be expected to authorize and fund those elements of the system which qualify under federal criteria.

Federal Financing Sources

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The Environmental Protection Agency, an independent administrative agency, is authorized to participate in the funding of water improvement facilities under the provisions of the Federal Water Pollution Control Act and subsequent amendments. Title II of the Act authorizes up to 75 percent of the cost of construction of a community's water treatment works, and up to 85 percent of certain special projects such as those which will result in substantial cost or energy savings.

Such grants require compliance with stringent federal guidelines and the preparation of planning, engineering and environmental impact reports. A priority list determines which projects are funded each year on the basis of relative need and benefits. Each year $75 million is available nationally for the funding of water treatment projects, so EPA is a viable funding source if a city or town is persistent and patient enough to fulfill the multiple requirements for participation.

FARMERS HOME ADMINISTRATION (FMHA)

Since 1963 the Farmers Home Administration of the U.S. Department of Agriculture has made available to small towns and rural areas in Oklahoma grants and loans for water supply and waste disposal projects. To qualify for FMHA financing a community or rural area must have a population under 10,000.

FMHA provides loans at five percent interest for periods up to 40 years, a rate extremely attractive to eligible applicants in today's financial market. Grants are also available in amounts up to 50 percent of project cost.

Since implementation of the funding program FMHA has made 968 loans totaling over $172 million; and grants totaling almost $39 million in Oklahoma. FMHA officials estimate they have financed projects serving 331,684 Oklahoma families.

As a result of the many requests to FMHA, processing can cause a long delay, during which rapidly escalating construction prices can cost the applicant community additional and often unavailable monies. However, no other reasonable financing alternative has existed for many towns and rural water districts, so they must wait until their projects are approved or seek interim financing.

HOUSING AND URBAN DEVELOPMENT (HUD)

The Department of Housing and Urban Development is authorized under the Housing and Community Development Act, as amended, to provide block grants for urban renewal, water and sewer projects, neighborhood development and construction of public facilities.

The program receives funds from annual Congressional appropriations, and is intended to provide adequate housing, a suitable environment and expanded economic opportunities for low-income groups. Since an adequate water supply is fundamental to the accomplishment of these objectives, water and sewer projects are often awarded priority.

Generally 80 percent of the funds available is earmarked for Standard Metropolitan Statistical Areas (SMSA's — cities of at least 50,000 population and urban counties of 200,000 or more) and 20 percent for nonmetropolitan areas. Since there are only three designated SMSA's in Oklahoma, it is unlikely that the state will receive a significant share of HUD funds. However, communities which qualify should consider seeking financial assistance for their water projects through this program.

OZARKS REGIONAL COMMISSION (ORC)

The Ozarks Regional Commission is a 5-state organization created to promote the economic development of Kansas, Oklahoma, Louisiana, Arkansas and Missouri. The Commission maintains an active grant program including assistance in financing water supply, distribution and treatment facilities.

Assistance from ORC is usually supplemental to other federal grants, with ORC allowing the primary federal agency to determine the project scope and funding. Conditions of ORC grants are that they create jobs and present a long-term economic benefit.

Legislation allows the Commission to finance up to 80 percent of project costs, but since funds stem from Congressional appropriations, ORC is forced to assess requests selectively to determine priority projects.

Many cities and towns in Oklahoma have been recipients of ORC grants, and others should seek the

Commission's assistance, particularly if supplemental funds for another federal grant are needed. During the 1978 fiscal year ORC awarded $2 million for projects in Oklahoma.

BUREAU OF RECLAMATION

The Bureau of Reclamation, an arm of the Department of Interior, is authorized under the Small Reclamation Projects Act of 1956, as amended, to make loans and grants in the 17 western states and Hawaii. Eligible projects must be either for irrigation or of a multipurpose nature. The maximum loan and/or grant is limited to two-thirds of a maximum allowable total project cost, which has been established at $29 million for fiscal year 1979.

Although many Oklahoma communities and rural water districts are eligible, no loans or grants under this program have been made in the state. The $1,000 application fee may discourage some potential participants, but if the communities could supply the fee, the financial assistance available through the Bureau of Reclamation should be of significant benefit.

ECONOMIC DEVELOPMENT ADM. (EDA)

The Economic Development Administration of the U.S. Department of Commerce makes available to communities grants and loans to promote industrial growth and development. Grant assistance up to 50 percent of the total eligible cost is provided, while long-term loans are made available at a rate established by current federal borrowing costs. EDA assistance is predicated upon budget limitations, since funding amounts depend on Congressional appropriations.

Although EDA assistance is intended to encourage industrial development, the recognition of the critical importance of an adequate water system to industrial growth should justify EDA's consideration of a community water project.

304 PROGRAM

A 1974 amendment to the Public Works and Economic Development Act established Section 304 which provides federal funds to be apportioned among states for use in supplementing or making certain grants and loans. Oklahoma's annual apportionment is approximately one-half million dollars.

A state contribution of at least 25 percent of the amount of funds used per project is required. The Oklahoma Legislature appropriates funds to the Department of Economic and Community Affairs to meet this matching requirement. However, the decision to use Section 304 funds is at the discretion of the Governor, providing all federal conditions are satisfied.

Use of these funds must be consistent with the state economic planning process, which stresses direct job creation and the leverage of additional public and private investments. Water supply, storage and distribution facilities may be involved in such efforts.

In 1979 the Oklahoma Legislature appropriated $68,000 toward the funding of 10 projects.

Local Financing

Communities generally have two options in generating local funds for water resource development: issuing municipal bonds or notes (either revenue or general obligation) and generating sales tax monies. A community should consider all these methods and choose the one or combination appropriate to local conditions.

MUNICIPAL BONDS OR NOTES

The tax-exempt status of municipal bonds makes them attractive to investors. The principal types of municipal bonds that have been used in the past are revenue bonds or notes and general obligation bonds. General obligation bonds are secured by the municipality pledging its full faith, credit and taxing power for payment of the bonds. All municipal general obligation bonds must be approved by a vote of the taxpayers.

The Oklahoma Constitution and Statutes limit the general obligation indebtedness of municipalities to five percent of the net assessed valuation for all nonutility-type improvements (10 percent if an absolute need exists), but place no legal limit on municipal indebtedness for utilities. Considered a utility, water systems are thus exempt from both the five and the 10 percent limit.

An alternate and often highly attractive means of financing water systems is by the sale of revenue bonds or notes, a type of municipal bond secured by a mortgage of all project-related properties and a pledge of the completed facility's earnings. Although Oklahoma law prohibits municipalities from issuing revenue bonds or notes directly, this method is legal for public trusts or authorities established by municipalities for that purpose.

The feasibility of issuing revenue bonds or notes depends on the ability of the facility's revenues to retire the bonds or notes and to pay operation and maintenance costs. The pledge of the project's revenues, plus the legal right to make an assessment against the property, give the bonds an advantage in the bond market.

A community or group of communities interested in funding a water project typically forms a public trust for the issue of bonds or notes, and subsequently retires them through revenues from the sale of water to residents and local industries. Although revenue bonds are a higher risk investment than general obligation bonds, many issues are currently rated as exceptional investments.

Securing voter support for a general obligation bond election may prove difficult. In some instances revenues from the facility can be placed in the sinking fund to be used to retire the bonds. If sufficient revenues are paid into the sinking fund, local taxpayers have no additional tax assessment — sometimes an attractive selling point for general obligation bond issues.

SALES TAX

If a city is collecting sales tax revenues beyond those necessary to maintain existing obligations, a portion of these taxes can be earmarked for community improvements. If not, the city can vote an additional sales tax levy to be applied toward a specific project or purpose. In either case, the revenue from sales tax can be applied toward retiring general obligation bonds or revenue bonds or notes.

Recent reticence on the part of taxpayers to further assess themselves indicates that communities may choose to rely on taxation as a financing mechanism only after all other alternatives have been eliminated.

State Financing

Many Oklahoma communities have been deprived of adequate water supplies because an appropriate funding mechanism was not available to them. A program of financial assistance is now available through Title 82 O.S. 1979, Section 1085.31, et. seq. (Senate Bill 215 of the First Session of the 37th Legislature). This legislation is designed to provide cities, towns and rural water districts with the funding necessary to construct water storage projects, distribution systems and treatment facilities. It authorizes the Oklahoma Water Resources Board to issue investment certificates in the form of revenue bonds and to establish a Water Resources Fund from the bond proceeds. The Board is authorized to loan money from this fund to qualified entities for the development or expansion of local water projects. Program guidelines describe qualified entities as all political subdivisions of the state, special-purpose water resource districts and public trusts or authorities.

Revenues from the completed project will be used to repay the loan, and the Board will retire the bond issues from repayments. The legislation, effective October 1, 1979, sets no limit on the amount of bonds to be issued, but places a $1.5 million ceiling on each loan. Funding from the program may be utilized in the acquisition, improvement, extension or construction of dams, reservoirs and other water storage projects; water distribution facilities; and filtration and treatment plants. It is the stated intent of the legislation to make funds available for the development of adequate water supplies to all Oklahoma communities experiencing water quantity or quality problems.

Although the financial assistance program is an innovative step toward the accomplishment of local water development goals, certain provisions hinder the potential effectiveness of the legislation. Specifically, the $1.5 million ceiling prevents the program from financing a major reservoir project. In order for the program to finance the comprehensive development necessary to meet the state's long-range water requirements, the ceiling must be raised substantially. Present provisions of the loan program allow for the achievement of only short-term goals. As these needs are fulfilled, enhanced funding levels should be considered by the Legislature if the state and regional water development projects of the scope necessary for implementation of the Oklahoma Comprehensive Water Plan are to be undertaken.

STUDIES AND RESEARCH

Continued Water Planning Studies

Inadequacies in funding and personnel have and will continue to limit the Oklahoma Water Resources Board in fulfilling its duties and responsibilities regarding future water development in Oklahoma. The Board staff is unquestionably too small to accomplish the immense task of developing, updating and implementing a state water plan. Water planning is expensive, so increased financial support for the Board is also essential. Unless the state is prepared to pay the cost, it must accept the probability that future goals cannot be effectively and efficiently achieved. Further, without sufficient funding appropriated for planning efforts, other states will have an advantage in obtaining any available federal monies.

In addition, increased appropriations are needed to allow for expansion of the basic data collection programs upon which planning efforts rely. These include well measurement programs, hydrologic studies of ground water basins and stream systems and information on water quality.

Water resources planning must take a multidisciplinary approach, requiring a professional staff of economists, engineers, geologists, hydrologists and biologists. The planning capabilities of the Oklahoma Water Resources Board must be increased in order to maintain and attract the professionals necessary to update and implement the Plan effectively. In addition, reliance on federal planners could be substantially reduced if the Board were adequately staffed.

The long lead time necessary for planning water projects of the magnitude described in this plan makes it imperative that the state begin now to adequately fund the appropriate planning studies

Research

Research provides the information necessary to formulate appropriate planning techniques. Additional research is needed to develop new techniques and programs for more effective utilization of existing data, and to increase general knowledge of present resources. Continued research will aid in overcoming the problems of resource development. The research programs which have been initiated should be expanded, including studies on the interdependence of ground and stream waters, their use and replenishment, and the relationship of ground water systems to the factors that influence them. Understanding return flows, natural and artificial recharge, conservation practices and wastewater reuse and their effects will insure the most efficient use of water resources. Continued investigations related to flood control, weather modification, evaporation minimization, seepage control and stream water appropriation could also contribute to improved water planning.

Research relying on computerized models to simulate the hydrologic behavior of ground water and stream water systems is needed to determine the effects of various alternatives without physically implementing them. Thus a wider array of alternatives can be considered in the development of future plans. Further water quality research on desalinization, reduction of nutrient content in runoff, industrial waste treatment and urban runoff effects is necessary if further degradation of the state's water resources is to be prevented.

Oklahoma boasts a variety of outstanding research programs, primarily at the state's two major universities. The Oklahoma Water Resources Research Institute at Oklahoma State University, primarily funded by the Office of Water Research and Technology of the the Department of Interior, annually sponsors a variety of scientific studies These studies emphasize research designed to address practical problems encountered in water resource planning and development. In addition, the College of Business Administration and Department of Agricultural Economics at OSU have been involved in water-related research, particularly in the area of economics.

The Bureau of Water and Environmental Resources Research at the University of Oklahoma is involved in numerous research programs, including the development of sophisticated computer models to project future water needs. The Center for Economic and Management Research has also conducted water-related research.

The continued funding of the various programs at both universities is vital. The wide range of expertise available from the academic community must continue to be utilized if water resource development is to progress.

Data Collection

Accurate and complete data are necessary in formulating any plan, particularly one of the scope of the Oklahoma Comprehensive Water Plan. Appropriate information must be collected on a regular and long-term basis to provide a complete range of alternatives.

The dynamic nature of hydrologic systems requires programs to monitor their reactions to man's activities. Changes generally occur gradually, sometimes requiring years of careful monitoring to detect particular trends. Detailed data on climate, water well levels and streamflow give direction to planning, project design and regulation. The Oklahoma Water Resources Board cooperates with the U.S Geological Survey in a statewide program to collect stream water and ground water quality and quantity data.

Hydrologic studies of each significant ground water basin, begun in 1967, collect data on water levels, water quality and saturated thickness which are correlated, analyzed and mapped to determine maximum annual yields. Ground water management programs can then be implemented where appropriate.

Recent water quality problems reported by many Oklahoma towns which rely on ground water for water supplies emphasize the need for more complete quality data.

Hydrologic studies of state stream systems are underway to determine the quantities of water available for appropriation. Data on deficient and surplus streamflows must also be collected, especially on the critically deficient stream systems in western Oklahoma.

To aid in the accumulation and dissemination of water-related data, the Oklahoma Water Resources Board is participating in the U.S. Geological Survey's National Water Use Program. This program is designed to develop a comprehensive statewide water use data inventory. It will include the documentation of the sources of water supply, where the water is being used, how it is being used, and how much is being consumed or delivered to others. The inventory will acquire current data and develop a data base and procedures for the continual collection, storage and retrieval of data. The overall objective of the program is to establish a system which will provide maximum accessibility of information to support planning, development, management, conservation and protection of our water resources.

Presently, data on different aspects of water use are available from various local, state and federal agencies. During FY 1980, with guidance from a Water Use Task Force, the Oklahoma Water Resources Board will evaluate Oklahoma's existing water use data collection programs and available storage and retrieval systems in order to develop a comprehensive water use data work plan. This work plan will outline the necessary tasks leading to implementation of the system in the spring of 1981.

Interstate Cooperation

In an attempt to explore all feasible solutions to maximize water development in the state, Oklahoma must consider the appropriateness of cooperating with surrounding states in the development of a regional water transport plan. Several federal and state studies presently underway are being assessed and Oklahoma's role in them should be analyzed prior to considering an interstate cooperative approach.

There has been an effort by the State of Texas to expand its state water planning to a regional basis including Arkansas, Louisiana, New Mexico and Oklahoma. The Texas Department of Water Resources, responsible for planning the development of that state's water resources, is currently developing a conceptual plan for the delivery of water from Arkansas to the water-deficient High Plains area. These studies indicate that the most feasible conveyance route could be via the southern water conveyance system proposed in the Oklahoma Comprehensive Water Plan.

By joining with Arkansas, Texas and New Mexico to develop a regional water distribution system, it is possible that a more cost-efficient project could be designed and constructed which would serve Oklahoma's interests as well as those of other states. By joining with surrounding states to equitably use surplus waters, Oklahoma would be assured of being able to put to beneficial use the water resources flowing through and originating in the state.

Six-State High Plains — Ogallala Aquifer Area Study

In 1976 the Six-State High Plains-Ogallala Aquifer Area Study was authorized by Congress to assess the water problems in the High Plains states. Under provisions of Public Law 94-587 and funding provided by the Economic Development Administration (EDA), the $6 million study is focusing on the rapidly depleting natural water and energy resources of the States of Oklahoma, Texas, New Mexico, Kansas, Colorado and Nebraska. The study with recommendations is scheduled for completion and submittal to Congress in July 1982.

The purpose of the study is clearly stated in the authorizing legislation as being "...to assure an adequate supply of food to the nation and to promote the economic vitality of the High Plains Region..." To fulfill this purpose, the study will assess various alternatives addressing the future water shortage problems of the High Plains area, including major interbasin water transfer plans.

The High Plains Study Area encompasses 225,000 square miles reaching from eastern New Mexico and the Panhandle of Texas and Oklahoma, northward through Colorado and Kansas, into southern Nebraska. See Figure 126. Much of the area is underlain by the Ogallala Formation, a major aquifer supplying water to the area's large agricultural economy

FIGURE 126 STUDY AREA SIX-STATE HIGH PLAINS—OGALLALA AQUIFER AREA STUDY

Due to low rainfall, irrigated agriculture in the region has increased dramatically during the last three decades. The region produces irrigated crops valued in excess of $2 million annually, 10 percent of the U.S. receipts from crops; and supports a $10 billion annual livestock production which supplies 40 percent of the nation's fed beef market. Recently declining water tables threaten to return the region to dryland farming and thereby to inflict severe economic consequences on the entire nation.

The study is being directed by the High Plains Study Council which is composed of the governors of the six states, their designees and a representative of the Economic Development Administration. In September 1978 the Council selected Camp Dresser and McKee, Inc. as prime contractor and coordinator of the Study, with Black and Veatch as joint venturer, and Arthur D. Little, Inc. as a major subcontractor. The Corps of Engineers received funds to evaluate alternative water transfer plans to meet future water needs of the study area, including the interstate transfer of water from sources within and outside the study area.

State involvement in the study was considered essential, with Congress allocating $2 million of the $6 million total to the states for state-level research. To date, each state has received $300,000 to conduct three elements of the High Plains Study: State Agricultural and Farm-Level Research, Energy Production Impacts and State Water Resources Evaluation and Impact Research, with the remaining $200,000 being held as a contingency fund.

The Oklahoma Water Resources Board has been designated by the Governor to act as Oklahoma's lead agency to accomplish the state research elements. The Board has subcontracted with the Department of Agricultural Economics at Oklahoma State University and the Center for Economic and Management Research at the University of Oklahoma to conduct the Agricultural and Farm-Level Research and the Energy Production Impacts, respectively. The Board will complete the Water Resources Evaluation and Impacts Research.

Much of the work on the Oklahoma Comprehensive Water Plan complements the EDA High Plains Study, and their coordination is imperative. The High Plains Study and its final recommendations could be of great importance to Oklahoma due to its regional approach to water development, which could eventually prove to be the most feasible means for the state to address its water distribution problems also.

Statewide Economic Impact Study

The water transfer component proposed in the Oklahoma Comprehensive Water Plan will have numerous direct and indirect economic benefits for all Oklahomans. The identification of total economic benefits is of extreme importance, and such benefits should be assessed in relation to the cost of the water transfer plan in order to determine its economic feasibility.

Under federal planning guidelines only primary benefits may be recognized, however, the forward and backward linkage or indirect effects of additional water supplies are also very important and must be considered in order to have a meaningful economic analysis. Such a statewide economic impact study assessing total economic benefits is essential in order to make an intelligent decision on whether or not to pursue a water transfer plan. Recognizing this need, the Oklahoma Legislature authorized and funded a study by the Oklahoma Water Resources Board, and the Board contracted with Oklahoma State University and Oklahoma University to assess the statewide economic impact of a water transfer system. The study will utilize several sophisticated computer models to assess the economic impacts on the state without water transfer and with water transfer. The $277,633 study cost will be provided by state appropriations and federal matching grants and is scheduled for completion by January, 1981.

The Center for Economic and Management Research (CEMR) at Oklahoma University is the coordinating agency and prime contracting unit for the study. The Department of Agricultural Economics and College of Business Administration at Oklahoma State University have been subcontracted to prepare a portion of the study, with each of the three research groups responsible for developing specific models which will be interrelated.

The major objectives of the study are to evaluate the impact of future water shortages on the state and regional economic activity through the year 2040; to evaluate the direct and indirect benefits of the statewide water transfer system to the economy of the state through the year 2040; and to evaluate the direct and indirect benefits of the statewide water transfer system to the economies of areas outside the State of Oklahoma.

The determination and evaluation of economic impacts are of great importance in making a final decision regarding actual construction and operation of a water transfer system. However, the distribution of costs for such a system is equally important. Since preliminary results indicate that a water transfer system is not economically feasible under federal guidelines, the state must be prepared to consider assuming any costs exceeding federal financial limits. An analysis of this state cost is paramount to the acceptance of such an expensive undertaking. The State Economic Impact Study will also include a State Net Benefits Analysis which will evaluate the distribution of costs on a regional level and identify the portion of costs attributed to nonresidents. Changes in the existing tax structure will be taken into account whenever possible to provide a more realistic breakdown of costs.

The study will not include a formal cost-benefit analysis of a transfer system. However, the economic impacts derived from the model and the costs provided by cooperating federal agencies should provide decisionmakers with information upon which to make competent choices.

Environmental Considerations

Environmental considerations reflect society's concern for and emphasis on the values of the natural environment. These considerations previously applied only to physical and biological systems, but now include such considerations as socioeconomic impacts and possible disruption of archeological and historic sites. Environmental impacts from future resource development must be a part of overall water planning efforts.

The Oklahoma Comprehensive Water Plan contains a cursory assessment of environmental impacts anticipated in the construction of the proposed water transfer system. Although this assessment is only preliminary in nature, it does provide for the mitigation of and compensation for adverse effects on fish and wildlife habitats of the Plan's major construction programs.

Prior to construction of any major conveyance system, environmental impact statements more accurately assessing future impacts will be necessary. If a system is federally financed, the responsible federal agencies must conduct a detailed environmental impact study. If it were to be state funded, the appropriate state agency or agencies would make the environmental evaluation. Environmental considerations include investigation of archeaological sites, biological studies to determine disruption of rare or endangered plants and animals, and planning to minimize aesthetic losses and displacement of families, farms, businesses and cemeteries.

Chloride Control Projects

Since 1957 the Federal Government has been studying methods to identify and control the natural salt pollution that renders the Arkansas and Red Rivers and many of their tributaries unfit for most beneficial uses. The U.S. Public Health Service and the Corps of Engineers cooperated to determine the source of the chlorides, and the Corps formulated several plans to eliminate and abate pollution from the natural salt emission areas.

Successful implementation of the proposed chloride control plans is essential to the Oklahoma Comprehensive Water Plan. Data from Chapter VI indicate that the northern water conveyance system alternative which assumes the projects to be operational and effective is somewhat less costly than the system without chloride control. Furthermore, efficient control of the salts would make additional sources of water available for local use.

The total estimated cost of the chloride control projects is $632.8 million, based on 1978 price levels. The Corps of Engineers is currently engaged in an extensive reevaluation of project economics. Preliminary results of that analysis using current technology indicate that the project in the Arkansas River Basin may not be economically justified at this time. The projects in the Red River Basin, however, do appear justified and preconstruction planning is continuing. Construction has been completed on one control project in Texas, and initiated on another nearby.

Reinforced state support of the Corps of Engineers' authorized Arkansas-Red River Basin Chloride Control Project is vital to fulfilling the future water needs of Oklahoma. The state will have solved many of its future water problems when this improved water becomes available for beneficial uses. At such time, water of better quality will be available to eastern Oklahoma and a greatly expanded supply of good quality water will be close to western Oklahoma.

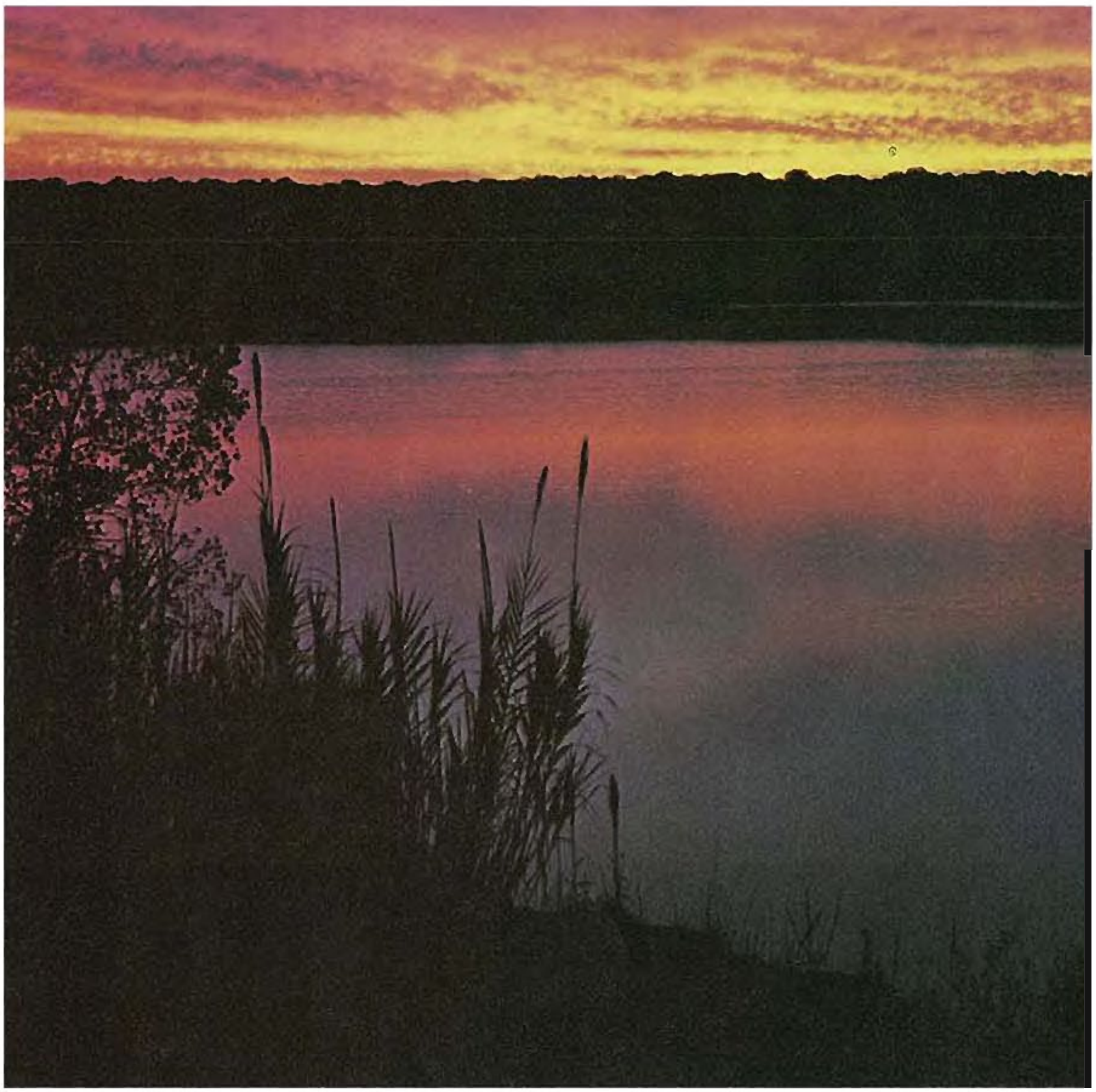
AUGMENTATION OF WATER RESOURCES

In the analysis of nontransfer alternatives included in Chapter I , the Oklahoma Water Resources Board has identified several methods to augment and/or prolong the state's water resources. Investigation of all these means should continue, and although they may not individually or collectively produce sufficient quantities of water to fulfill the state's needs, they can supplement local supplies.

Additional research in the technologies of weather modification, artificial recharge, control of water-wasting vegetation and desalination should be encouraged. However, preliminary to their consideration as viable sources of water supply is an accurate determination of the amounts of supplemental water such measures would yield, which quantification should be a primary function of future planning efforts.

Water conservation, as discussed in Chapter III, remains another alternative worthy of emphasis. Wastewater reuse has emerged recently as an increasingly effective tool in the conservation of municipal an industrial water. In addition, the formation of water management districts is an integral part of any water conservation program, and therefore the foundation of any practical water transfer concept. It is the responsibility of the state to provide the leadership necessary to the organization and financing of individual or group efforts to conserve Oklahoma's precious water resources.

CHAPTER IX
CONCLUSIONS AND RECOMMENDATIONS



CONCLUSIONS

All of Oklahoma has great potential for future economic expansion, if adequate supplies of good quality water can be developed and properly distributed. Present water use for all purposes in Oklahoma is estimated to be 2.4 million acre-feet annually, while projections of future water use indicate over 6.9 million acre-feet per year may be needed by the year 2040. Irrigation is currently the largest use of water, however, depletion of ground water resources in western Oklahoma is threatening the future of irrigated agriculture.

In addition, a sharp escalation in population in the central Oklahoma metropolitan area is stretching existing water supplies. Also, many Oklahoma communities lack reliable sources of good quality water due to natural or man-made pollution and inadequate or outdated treatment and distribution systems. Without immediate attention, these problems pose a very real threat to Oklahoma's future growth and prosperity. The Oklahoma Comprehensive Water Plan presents a flexible guide for development of the state's water resources on a regional basis and also proposes a means of distributing surplus water from eastern Oklahoma to water-deficient areas in central and western Oklahoma.

Development of the projects necessary to meet the 2040 water needs of the state is estimated at January 1978 price levels to cost approximately $11 billion, which does not include local distribution and treatment facilities. Regional plans of development show maximum local water development could cost $3 billion, but despite optimum local development, five of the eight planning regions will face future water deficits.

A total of approximately 800,000 acres is projected to be irrigated from all the proposed Regional Plans of Development by the year 2040.

An assessment of nontransfer alternatives indicates they can provide only supplemental water supplies and cannot be relied upon to provide the quantities of water required to meet Oklahoma's future needs.

To meet the projected water deficits of central and western Oklahoma, construction of a statewide water conveyance system consisting of a northern system for the Arkansas River Basin and a southern system for the Red River Basin, should be considered. The cost for the northern conveyance system is $5.3 billion, and for the southern conveyance system, $2.5 billion. At ultimate development an annual 1.2 million acre-feet of water would be transferred through the northern system, and 1.3 million acre-feet through the southern system for municipal, industrial, cooling water and irrigation purposes.

The systems would be independent, with each being built in stages in order to minimize the necessary investment costs as water demands increase.

Eleven existing reservoirs are included in both systems to maximize the use of existing projects. A total of 12 proposed and two authorized reservoirs would be constructed as part of the conveyance systems. The northern system would be 630 miles in length and the southern system, 500 miles long. Over 900,000 acres would be irrigated with imported water in northwestern and southwestern Oklahoma. The average annual equivalent benefits of irrigation water from the system are estimated to be $25 million. These benefits reflect only primary impacts and do not include indirect benefits accruing from the water conveyance system.

Neither conveyance system's irrigation component is economically justified under federal guidelines, which assess only primary benefits. The Statewide Economic Impact Study scheduled for completion in 1981 will quantify the indirect benefits, and through inclusion of secondary and tertiary benefits, could prove the systems feasible at least from the state viewpoint. The municipal and industrial component of each system is economically justified under the assumption that municipal and industrial benefits will equal costs.

According to projections by the Planning Committee included in the proposed Regional Plans of Development, the amount of surplus water available from all sources in eastern Oklahoma is six million acre-feet, after allowances for local use and export. Furthermore, existing Oklahoma statutes provide adequate and positive assurances to eastern Oklahoma that its future water requirements will be met prior to implementation of any large-scale water conveyance system.

Even if future water needs escalate to levels projected by local planners in eastern Oklahoma, there will be enough water to meet such needs, as well as the import needs of central and western Oklahoma, and still have a surplus exceeding 3.7 million acre-feet per year.

If ground water pumping in the Oklahoma Panhandle continues at present rates, it is unlikely that the northern conveyance system could be completed in time to prevent virtual cessation of ground water irrigation, forcing area farmers back to dryland farming. Nor is it likely that the southern water conveyance system could be finished in time to furnish municipal and industrial water to central Oklahoma before severe water shortages and attendant social and economic reactions become apparent.

Inadequate distribution systems are a statewide problem requiring immediate attention. Numerous cities, towns and rural water districts do not have the fiscal capability to finance needed water systems and therefore require assistance in constructing these facilities from federal programs and/or the state financial assistance program provided by 82 O.S. 1979, Section 1085.31, et seq.

The citizens of Oklahoma must unite in molding their future through endorsement of local and statewide water development plans capable of providing the water needed to assure the state continued prosperity.

RECOMMENDATIONS

Based upon analyses of the detailed studies documented in the Oklahoma Comprehensive Water Plan, the Oklahoma Water Resources Board offers the following recommendations:

- that the Governor and Legislature accept the Oklahoma Comprehensive Water Plan as a general guidance document assuring the orderly control, protection and management of the water and related land resources of Oklahoma.

- that all state agencies and political subdivisions of the state involved in water-related activities take due cognizance of the Oklahoma Comprehensive Water Plan in carrying out their duties and responsibilities.

- that the Federal Government recognize the Oklahoma Comprehensive Water Plan as a guide in establishing priorities for planning, authorizing and funding of federal projects in Oklahoma.

- that the U.S. Army Corps of Engineers resume currently suspended feasibility level investigations on the water conveyance portion of the Central Oklahoma Project (COP).

  (See Chapter VI, page 168 "Alternative Water Transfer Plans Considered" and Chapter I, page 3, "Participation.")

- that the Federal Government recognize that primary authority and responsibility for water resources planning, development and regulation in Oklahoma rest with the state.

- that the Governor and Legislature support continuation and expansion of the state's water development financial assistance program.

  (See Chapter VIII, page 200, "State Financing" and Appendix C, Figure 6.)

- that the Governor, the Legislature and the Oklahoma Congressional delegation continue to support the Arkansas-Red River Basin Chloride Control projects as the most practical and economical means of achieving needed water quality improvements in Oklahoma.

  (See Chapter I, page 14, "Desalination and Chloride Control Projects," Chapter VIII, page 204, "Chloride Control Projects" and Chapter IV, page 72, "Natural Pollution.")

- that the Legislature adopt floodplain management legislation adequate to insure every Oklahoma community can qualify for federally subsidized floodplain insurance.

  (See Chapter IV, page 70, "Flooding.")

- that the Governor and Legislature strengthen the state's water programs by supporting the Oklahoma Water Resources Board in carrying out its statutory duties and responsibilities.

  (See Chapter VIII, page 200, "State Financing," "Continued Water Planning Studies" and "Research.")

- that the Governor and Legislature support the development and implementation of a comprehensive weather modification program for the State of Oklahoma.

  (See Chapter I, page 13, "Weather Modification.")

- that the Governor and Legislature take appropriate measures to promote water conservation in the state in order to lessen the impact of projected future shortages.

  (See Chapter III, "Water Conservation in Oklahoma.")

- that the Governor and Legislature take appropriate measures to insure that the citizens of Oklahoma are educated and informed in all matters pertaining to water in order that the state's water resources are adequately protected and placed to maximum beneficial use.

APPENDIX A

FIGURE 1 CHEMICAL ANALYSES OF PUBLIC WATER SUPPLIES (By Planning Region)

SOUTHEAST PLANNING REGION

ATOKA CO.

CITY		Atoka (A)	Caney	Tushka RWD 2	Wardville RWD 1
SOURCE OF SUPPLY		Atoka Lake	Ground Water	Ground Water	Wardville Lake
DATE OF ANALYSIS		2-78	9-77	5-77	2-79
PARAMETERS	UNIT				
Total Hardness	mg/L	59	84	281	67
Total Alkalinity	mg/L	45	63	257	68
Chloride	mg/L	6	27	21	10
Sulfate	mg/L	41	13	17	14
Fluoride	mg/L	0.10	0.09	0.24	0.19
Dissolved Solids	mg/L	100	171	—	121
pH	SU	7 7	6.1	7.2	6.9
Sodium	mg/L	16	10	18	17
Nitrite-Nitrate	mg/L	0.4	0 6	0.5	1 2
Iron	µg/L	<100	160	<200	190
Manganese	µg/L	<20	<10	<10	<20
Silver	µg/L	<1	<2	2	<1
Cadmium	µg/L	<1	<1	3	<1
Chromium	µg/L	13	5	11	16
Copper	µg/L	14	39	—	17
Lead	µg/L	6	<5	39	9
Zinc	µg/L	9	10	—	40
Barium	µg/L	<100	<100	300	<100
Arsenic	µg/L	<2	<1	<1	<2
Selenium	µg/L	<1	1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0 5	<0.5

(A) Serves RWD 4 and Stringtown

BRYAN CO.

CITY		Achille	Bennington	Bokchito	Caddo	Calera	Colbert (A)	Durant (B)	Hendrix-Kemp Water Dist. Inc.	Kenefic
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Blue River	Ground Water	Ground Water
DATE OF ANALYSIS		9-77	9-77	9-77	9-77	9-77	9-77	6-77	9-77	9-77
PARAMETERS	UNIT									
Total Hardness	mg/L	32	3	4	5	130	46	201	60	77
Total Alkalinity	mg/L	116	539	580	292	226	36	179	65	208
Chloride	mg/L	10	41	28	9	19	9	8	9	12
Sulfate	mg/L	11	85	54	45	74	5	18	7	100
Fluoride	mg/L	0.28	1.6	1 15	0.24	0.35	0 20	0.25	0.34	0.28
Dissolved Solids	mg/L	171	787	744	417	347	117	—	158	367
pH	SU	7.2	9.3	6.7	8 6	7.7	6 3	7 7	9.4	7.2
Sodium	mg/L	48	760	190	150	83	5.0	<5.0	10	99
Nitrite-Nitrate	mg/L	<0.1	<0 1	0.3	0.6	<0 1	3.4	0 2	5.8	0 2
Iron	µg/L	1770	<100	<100	<100	1430	<100	<200	<100	685
Manganese	µg/L	48	115	<10	15	<10	<10	<10	<10.0	290
Silver	µg/L	<2	3	3	<2	<2	<2	3	<2	2
Cadmium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	µg/L	<5	<5	<5	<5	<5	<5	8	<5	<5
Copper	µg/L	8	2	10	4	2	63	—	850	5
Lead	µg/L	<5	10	10	<5	7	<5	4	<5	8
Zinc	µg/L	95	15	27	15	260	29	—	55	1560
Barium	µg/L	<100	<100	<100	<100	<100	<100	400	<100	<100
Arsenic	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0 5	<0.5	<0.5	<0 5	<0.5	1 0	<0.5	<0 5

(A) Serves RWD 1
(B) Serves RWD 2 & 5

CHOCTAW CO.

CITY		Boswell	Fort Towson	Hugo (A)	Soper	Swink (B)
SOURCE OF SUPPLY		Ground Water	Ground Water	Hugo Res.	Ground Water	Valliant
DATE OF ANALYSIS		5-77	5-77	5-77	5-77	4-79
PARAMETERS	UNIT					
Total Hardness	mg/L	288	163	222	216	56
Total Alkalinity	mg/L	242	163	250	222	34
Chloride	mg/L	49	6	6	6	<1
Sulfate	mg/L	76	33	41	10	29
Fluoride	mg/L	.7	<.1	1	2	<0.06
Dissolved Solids	mg/L	—	—	—	—	118
pH	SU	7 2	7.7	7.5	7 6	8 4
Sodium	mg/L	—	—	—	—	<10
Nitrite-Nitrate	mg/L	2.7	0.9	<0 1	<0.1	0 3
Iron	µg/L	620	<100	910	240	<100
Manganese	µg/L	140	<10	140	230	20
Silver	µg/L	<1	<1	3	2	<20
Cadmium	µg/L	2	1	2	1	<2
Chromium	µg/L	10	9	7	8	26
Copper	µg/L	—	—	—	—	<40
Lead	µg/L	18	11	11	10	<10
Zinc	µg/L	—	—	—	—	<40
Barium	µg/L	100	<100	200	160	390
Arsenic	µg/L	<1	1	2	<1	<2
Selenium	µg/L	<3	<3	<3	<3	<1
Mercury	µg/L	<1.2	<1.2	<0 5	<0.5	<0 5

(A) Serves RWD 1
(B) Purchases from Valliant, McCurtain County

COAL CO.

CITY		Coalgate (A)	Lehigh	Tupelo
SOURCE OF SUPPLY		Coalgate Lake Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		5-77	5-77	5-77
PARAMETERS	UNIT			
Total Hardness	mg/L	35	45	75
Total Alkalinity	mg/L	7	206	193
Chloride	mg/L	2	90	54
Sulfate	mg/L	30	20	163
Fluoride	mg/L	0.08	0 19	0.22
Dissolved Solids	mg/L	—	—	—
pH	SU	6.5	8 2	7 8
Sodium	mg/L	<10	102	167
Nitrite-Nitrate	mg/L	0.2	0 4	0.4
Iron	µg/L	200	<200	680
Manganese	µg/L	10.0	<10.0	120.0
Silver	µg/L	<1	1	2
Cadmium	µg/L	<1	2	<1
Chromium	µg/L	6	5	<1
Copper	µg/L	—	—	—
Lead	µg/L	8	6	8
Zinc	µg/L	—	—	—
Barium	µg/L	500	400	700
Arsenic	µg/L	<1	<1	<1
Selenium	µg/L	<1	<1	<1
Mercury	µg/L	0.7	0.9	0.9

(A) Serves Centrahoma Water Co Inc Clarita-Olney Water Inc., and RWD 1

JOHNSTON CO.

CITY		Bromide	Coleman	Mill Creek	Mannsville RWD 2	Ravia	Tishomingo	Wapanucka	RWD 3 (A)
SOURCE OF SUPPLY		Spring	Ground Water	Ground Water	Ground Water	Ground Water	Pennington Circle	Wapanucka City Lake	Ground Water
DATE OF ANALYSIS		4-78	4-78	4-78	4-78	4-78	4-78	4-78	5-78
PARAMETERS	UNIT								
Total Hardness	mg/L	375	144	260	337	439	211	270	275
Total Alkalinity	mg/L	332	128	315	310	445	205	250	268
Chloride	mg/L	6	31	6	31	18	8	27	5
Sulfate	mg/L	14	23	14	31	58	20	21	9
Fluoride	mg/L	0 13	0 26	0 20	0 18	0 21	0 16	0 15	0.14
Dissolved Solids	mg/L	332	225	312	400	510	258	293	326
pH	SU	7 3	7 0	7 5	7 0	7.3	7.7	8.3	7 4
Sodium	mg/L	12.0	30.0	10.0	22	35	7.0	17.0	15.0
Nitrite-Nitrate	mg/L	0 8	0.6	0 3	1 3	0.3	0 2	2.0	0.3
Iron	µg/L	<50	70	<50	490	<50	250	160	<50
Manganese	µg/L	<10	20	<10	10	10	<10	10	30
Silver	µg/L	2	<2	<2	2	3	<2	<2	<2
Cadmium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	µg/L	30	12	20	15	20	19	20	16
Copper	µg/L	7	18	5	51	22	8	4	15
Lead	µg/L	28	11	28	35	38	23	23	15
Zinc	µg/L	74	230	59	565	295	325	81	240
Barium	µg/L	<50	<50	100	<50	150	<50	<50	<50
Arsenic	µg/L	1	<1	<1	<1	<1	1	<1	<1
Selenium	µg/L	<1	6	<1	<1	1	<1	<1	<1
Mercury	µg/L	<0 5	<0 5	<0 5	<0 5	<0 5	<0 5	<0 5	<0.5

(A) Serves RWD 1

McCURTAIN CO.

CITY		Broken Bow	Clebit	Garvin	Haworth	Idabel	Millerton RWD 2	Mt. Fork RWD	RWD 1	Valliant (A)	Wright City
SOURCE OF SUPPLY		Broken Bow Res	Ground Water	Ground Water	Ground Water	Little River	Ground Water	Pine Creek	Little River	Little River	Little River
DATE OF ANALYSIS		4-79	5-78	2-78	5-78	4-79	4-78	4-79	4-79	4-79	4-79
PARAMETERS	UNIT										
Total Hardness	mg/L	20	445	152	61	33	25	18	50	56	44
Total Alkalinity	mg/L	24	169	169	10	27	6	22	22	34	22
Chloride	mg/L	<1	7	4	<2	<1	<2	<1	<1	<1	<1
Sulfate	mg/L	11	37	17	31	23	4	9	44	29	34
Fluoride	mg/L	<0.06	0.15	0.09	0.07	0.14	0.06	<0.06	<0.06	<0.06	0.1
Dissolved Solids	mg/L	46	665	261	103	83	41	50	115	118	96
pH	SU	6.6	6.8	7.7	7.2	7.2	7.2	6.3	6.1	8.4	7
Sodium	mg/L	<10	45	35	7 0	<10	<5	<10	<10	<10	<10
Nitrite-Nitrate	mg/L	0.4	0.1	<0.1	0 3	0 3	0 3	0 3	0.2	0 3	0 3
Iron	µg/L	100	340	340	90	<100	2700	100	<100	<100	<100
Manganese	µg/L	40	1100	50	40	<20	20	20	<20	20	<20
Silver	µg/L	<20	3	<2	<2	<20	<2	<20	<20	<20	<20
Cadmium	µg/L	<2	<1	<1	<1	<2	<1	<2	<2	<2	<2
Chromium	µg/L	28	19	23	16	28	20	<27	31	26	30
Copper	µg/L	<40	4	4	<2	<40	38	<40	<40	<40	<40
Lead	µg/L	<10	18	7	<15	<10	<5	<10	<10	<10	<10
Zinc	µg/L	50	205	160	20	<40	73	<40	<40	<40	<40
Barium	µg/L	100	170	60	<50	110	<50	<100	290	280	190
Arsenic	µg/L	<2	<1	<1	<1	<2	<1	<2	<2	<2	<2
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0 5	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Serves Forest Grove Water Corp., Swink Water Corp. Choctaw County.

PONTOTOC CO.

CITY		Ada (A)	Allen	Francis	Roff	Stonewall
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		12-76	12-76	12-76	12-76	12-76
PARAMETERS	UNIT					
Total Hardness	mg/L	331	—	—	—	—
Total Alkalinity	mg/L	336	—	—	—	—
Chloride	mg/L	9	—	—	—	—
Sulfate	mg/L	14	—	—	—	—
Fluoride	mg/L	0.1	0.10	1.9	0 7	0.5
Dissolved Solids	mg/L	370	—	—	—	—
pH	SU	7	—	—	—	—
Sodium	mg/L	—	—	—	—	—
Nitrite-Nitrate	mg/L	1.0	4.8	<0.1	0.1	0.1
Iron	µg/L	0	—	—	—	—
Manganese	µg/L	—	—	—	—	—
Silver	µg/L	2	1	8	2	3
Cadmium	µg/L	<1	<1	<1	<1	<1
Chromium	µg/L	11	14	10	14	12
Copper	µg/L	—	—	—	—	—
Lead	µg/L	10	5	21	10	14
Zinc	µg/L	—	—	—	—	—
Barium	µg/L	<2000	<2000	<2000	<2000	<2000
Arsenic	µg/L	<1	<1	<1	3	<1
Selenium	µg/L	1	<1	<1	<1	<1
Mercury	µg/L	<0 5	0.6	<0.5	<0.5	<0.7

(A) Serves RWD 1, 2, 3, 4, 5, 7, 8 and Fittstown RWD 6

PUSHMATAHA CO.

CITY		Antlers (A)	Clayton (B)	RWD 2 (C)
SOURCE OF SUPPLY		Hugo Res.	Kiamichi River	Talihina
DATE OF ANALYSIS		3-79	3-79	N/A
PARAMETERS	UNIT			
Total Hardness	mg/L	64	66	
Total Alkalinity	mg/L	12	10	
Chloride	mg/L	2	1	
Sulfate	mg/L	53	65	
Fluoride	mg/L	<0.06	0.07	
Dissolved Solids	mg/L	122	91	
pH	SU	7.4	6.3	
Sodium	mg/L	<10	<10	
Nitrite-Nitrate	mg/L	0.5	0.4	
Iron	µg/L	230	240	
Manganese	µg/L	<20	20	
Silver	µg/L	<2	<2	
Cadmium	µg/L	<2	<2	
Chromium	µg/L	29	29	
Copper	µg/L	<4	98	
Lead	µg/L	14	15	
Zinc	µg/L	220	12	
Barium	µg/L	<100	100	
Arsenic	µg/L	<2	<2	
Selenium	µg/L	<1	<1	
Mercury	µg/L	<0.5	<0 5	

(A) Serves RWD 3.
(B) Serves RWD 1
(C) Purchases water from Talihina, LeFlore County

CENTRAL PLANNING REGION

CANADIAN CO.

CITY		Calumet	El Reno (A)	Mustang	Okarche	Piedmont	RWD 1	Union City	Yukon
SOURCE OF SUPPLY		Ground Water	Ground Water	Oklahoma City	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		8-78	8-78		11-78	4-79	11-78	3-78	11-79
PARAMETERS	UNIT								
Total Hardness	mg/L	156	324		318	87	280	513	31
Total Alkalinity	mg/L	292	187		267	273	192	376	256
Chloride	mg/L	49	154		63	77	12	27	22
Sulfate	mg/L	219	278		46	298	310	305	25
Fluoride	mg/L	1.45	0.51		0.35	0.8	0.26	0.71	0.25
Dissolved Solids	mg/L	728	861		476	452	406	996	4290
pH	SU	8.5	7.8		7.4	7.8	7.1	7.8	8.7
Sodium	mg/L	201	160		72	145	57	160	155
Nitrite-Nitrate	mg/L	0.5	0.7		1.5	0.2	5.5	0.1	0.8
Iron	µg/L	540	440		<300	<300	<300	1660	<100
Manganese	µg/L	20	220		<20	<20	<20	390	<20
Silver	µg/L	2	3		<2	<2	<2	3	<3
Cadmium	µg/L	1	1		<1	<1	<1	<1	<2
Chromium	µg/L	14	12		<5	38	<5	25	42
Copper	µg/L	17	315		100	83	130	21	<40
Lead	µg/L	8	10		18	7	8	21	<20
Zinc	µg/L	31	160		65	38	1000	88	39
Barium	µg/L	<100	<100		286	214	357	130	140
Arsenic	µg/L	3	<1		2	<5	<1	1	62
Selenium	µg/L	<1	<1		4	23	<1	<1	10
Mercury	µg/L	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<5

(A) Serves Heaston Rural Water Corp.

CLEVELAND CO.

CITY		Lexington	Moore	Noble	Norman
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Thunderbird Lake Ground Water
DATE OF ANALYSIS		6-77	6-77	6-77	6-77
PARAMETERS	UNIT				
Total Hardness	mg/L	35	177	415	113
Total Alkalinity	mg/L	343	281	234	86
Chloride	mg/L	177	8	123	31
Sulfate	mg/L	163	<2	484	34
Fluoride	mg/L	0.51	0.38	0.86	0.9
Dissolved Solids	mg/L	823	299	1292	161
pH	SU	8.2	7.9	8.1	8.4
Sodium	mg/L	350	63	390	24
Nitrite-Nitrate	mg/L	0.1	0.5	0.4	0.1
Iron	µg/L	<200	<200	<200	<200
Manganese	µg/L	<10	<10	20	<10
Silver	µg/L	2	1	3	<1
Cadmium	µg/L	2	1	3	1
Chromium	µg/L	31	24	25	13
Copper	µg/L	7	15	13	—
Lead	µg/L	7	5	13	5
Zinc	µg/L	58	13	390	—
Barium	µg/L	400	700	800	200
Arsenic	µg/L	4	<1	30	<1
Selenium	µg/L	6	6	6	<1
Mercury	µg/L	1.4	<0.5	<0.5	<0.5

McCLAIN CO.

CITY		Blanchard	Byars	Goldsby RWD 5	Newcastle	Purcell (A)	RWD 1 (B)	Washington	Wayne	Wayne RWD 8 (C)
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	City Lake Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		7-77	6-77	7-77	6-77	9-77	6-77	7-77	6-77	6-77
PARAMETERS	UNIT									
Total Hardness	mg/L	450	197	556	546	409	428	430	384	384
Total Alkalinity	mg/L	375	296	615	287	369	278	367	375	338
Chloride	mg/L	23	35	28	104	26	37	37	23	14
Sulfate	mg/L	35	32	202	278	—	284	44	64	54
Fluoride	mg/L	0.23	0.34	0.46	0.47	0.35	0.49	0.25	0.5	0.2
Dissolved Solids	mg/L	500	435	1037	907	621	864	515	526	456
pH	SU	7.6	7.2	8.8	7.5	7.4	7.1	7.3	7.3	7.3
Sodium	mg/L	29	94	120	104	70	132	39	30	53
Nitrite-Nitrate	mg/L	4.3	4	1.1	0.8	0.5	3.4	4.8	0.6	0.4
Iron	µg/L	<100	230	1700	<200	<100	<200	220	1600	330
Manganese	µg/L	<10	20	1000	310	300	<10	10	260	60
Silver	µg/L	4	4	5	3	<2	4	4	3	3
Cadmium	µg/L	1	<1	1	<1	<1	1	<1	<1	<1
Chromium	µg/L	10	<5	20	15	5	10	<5	20	25
Copper	µg/L	23	14	5	24	31	280	45	120	125
Lead	µg/L	5	11	18	20	<5	23	12	33	5
Zinc	µg/L	22	315	21	35	30	478	295	66	21
Barium	µg/L	483	<300	<100	<300	300	<300	600	700	<300
Arsenic	µg/L	2	<1	1	3	<1	1	2	1	<1
Selenium	µg/L	<1	<1	1	<1	<1	7.3	1	<1	<1
Mercury	µg/L	1.5	<0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Serves RWD 2, 3, & 7
(B) Serves Rosedale
(C) Purchases water from Half-Circle J.H. Ranch Inc.

OKLAHOMA CO.

CITY		Bethany	Choctaw	Deer Creek	Del City	Edmond	Harrah
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Thunderbird Lake Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		7-79	2-79	2-79	5-77	3-79	2-79
PARAMETERS	UNIT						
Total Hardness	mg/L	143	174	54	200	123	99
Total Alkalinity	mg/L	60	173	312	202	55	198
Chloride	mg/L	129	10	145	37	115	48
Sulfate	mg/L	158	8	46	17	321	24
Fluoride	mg/L	0.19	0.17	0.80	0.8	1.15	0.34
Dissolved Solids	mg/L	504	198	618	—	622	421
pH	SU	9.5	7.3	8.2	7.9	7.3	7.9
Sodium	mg/L	124	12	219	—	192	95
Nitrite-Nitrate	mg/L	2.5	0.3	0.6	0.1	1.5	0.5
Iron	µg/L	800	<100	850	<200	<100	21
Manganese	µg/L	5	<20	5	<10	<20	1
Silver	µg/L	<2	1	<2	3	<2	<2
Cadmium	µg/L	<1	<1	1	<1	<2	<1
Chromium	µg/L	21	21	63	4	85	37
Copper	µg/L	2	9	19	—	33	6
Lead	µg/L	10	26	8	5	17	6
Zinc	µg/L	6	14	15	—	10	7
Barium	µg/L	<100	180	<100	400	100	<100
Arsenic	µg/L	<2	<2	26	<1	21	<2
Selenium	µg/L	<1	<1	154	<1	38	10
Mercury	µg/L	<0.5	0.6	<0.5	<0.5	<0.5	<0.5

OKLAHOMA CO.
Continued

CITY		Independent Water Corp.	Jones	Luther	Midwest City	Nichols Hills	Oklahoma City (A)*	Spencer
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Thunder-bird Lake Ground Water	Ground Water	Lakes Hefner, Overholser & Atoka	Ground Water
DATE OF ANALYSIS		3-79	2-79	2-79	5-77	2-79	2-79	2-79
PARAMETERS	UNIT							
Total Hardness	mg/L	62	193	271	205	13	223	233
Total Alkalinity	mg/L	427	192	230	189	197	28	232
Chloride	mg/L	88	8	204	35	79	164	8
Sulfate	mg/L	125	4	89	23	16	222	4
Fluoride	mg/L	0.90	0.21	0.28	1.1	0.29	1.01	0.18
Dissolved Solids	mg/L	970	220	701	—	376	613	257
pH	SU	7.2	7.4	7.6	7.7	8.3	9.3	7.4
Sodium	mg/L	290	10	165	—	140	123	11
Nitrite-Nitrate	mg/L	2	0.5	3	<0.1	0.3	0.1	0.5
Iron	µg/L	100	20	35	<200	<100	<100	39
Manganese	µg/L	<20	2	3	<10	<20	<20	2
Silver	µg/L	<20	<2	<2	2	<1	2.0	<2
Cadmium	µg/L	<2	<1	<1	<1	<1	<1.0	<1
Chromium	µg/L	243	20	28	4	42	18.0	19
Copper	µg/L	90	6	6	—	12	3.0	25
Lead	µg/L	<10	9	11	6	10	14.0	12
Zinc	µg/L	<40	140	110	—	5	2.0	12
Barium	µg/L	150	230	230	300	<100	<100	640
Arsenic	µg/L	6	<2	<2	<1	5	<2	<2
Selenium	µg/L	3	<1	6	<1	39	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Serves Mustang, Yukon, Canadian RWD 3 and Piedmont in Canadian Co. and emergency supply to Nichols Hills and Del City.
*Analysis taken from water supply treated at Lake Hefner facility.

POTTAWATOMIE CO.

CITY	UNIT	Maud	McLoud	Shawnee	Tecumseh	Wanette
SOURCE OF SUPPLY		N/A	Ground Water	City Lake	City Lake Ground Water	Ground Water
DATE OF ANALYSIS			3-78	5-78	8-78	3-78
Total Hardness	mg/L		97	106	113	511
Total Alkalinity	mg/L		197	123	88	364
Chloride	mg/L		18	24	26	238
Sulfate	mg/L		5	26	44	25
Fluoride	mg/L		0.29	0.80	0.69	0.27
Dissolved Solids	mg/L		250	165	239	748
pH	SU		7.9	7.5	7.9	8.1
Sodium	mg/L		58	16	34	92
Nitrite-Nitrate	mg/L		0.2	0.1	0.2	0.1
Iron	µg/L		120	110	80	130
Manganese	µg/L		<10	10	10	70
Silver	µg/L		<2	<2	<2	3
Cadmium	µg/L		<1	<1	<1	<1
Chromium	µg/L		32	13	16	22
Copper	µg/L		18	39	14	95
Lead	µg/L		13	<5	18	51
Zinc	µg/L		32	5	21	110
Barium	µg/L		100	110	110	1300
Arsenic	µg/L		1	<1	<1	<1
Selenium	µg/L		4	<1	<1	<1
Mercury	µg/L		<0.5	<0.5	<0.5	<0.5

SOUTH CENTRAL PLANNING REGION

CARTER CO.

CITY		Ardmore	Healdton	Lone Grove	Ratliff City	Southern Oklahoma Water	West Carter Co. RWD	Wilson
SOURCE OF SUPPLY		Ground Water City Lake	Ground Water	Ground Water	Ground Water	Arbuckle Lake	Ground Water	Ground Water
DATE OF ANALYSIS		1-79	6-78	6-78	6-78	12-78	6-78	6-78
PARAMETERS	UNIT							
Total Hardness	mg/L	167	23.4	281	106	172	7	53
Total Alkalinity	mg/L	146	565	297	503	167	506	373
Chloride	mg/L	10	197	28	27	62	18	16
Sulfate	mg/L	—	70	79	161	23	61	72
Fluoride	mg/L	0.3	2.7	0.35	1.6	0.33	1.2	0.75
Dissolved Solids	mg/L	212	1158.7	451	840	298	652	526
pH	SU	—	8.7	7.5	8.6	8	9	8.7
Sodium	mg/L	< 5	250	43	270	25	240	173
Nitrite-Nitrate	mg/L	0.2	0.3	0.2	0.1	0.1	<0.1	<0.1
Iron	µg/L	140	140	450	250	150	200	200
Manganese	µg/L	20	<20	40	<20	<20	<20	<20
Silver	µg/L	< 2	2	< 2	< 2	< 2	< 2	< 2
Cadmium	µg/L	< 1	1	1	1	< 1	1	1
Chromium	µg/L	< 5	115	< 5	< 5	< 5	5	7
Copper	µg/L	4	6	31	26	4	8	115
Lead	µg/L	8	< 5	16	11	8	< 5	8
Zinc	µg/L	12	39	31	6	7	16	30
Barium	µg/L	<100	< 100	100	160	<100	<100	100
Arsenic	µg/L	<1	< 1	< 1	< 1	<1	< 1	< 1
Selenium	µg/L	<1	ND	< 1	< 1	< 1	< 1	< 1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

GARVIN CO.

CITY		Elmore City (A)	Lindsay (B)	Maysville (C)	Paoli	Pauls Valley (D)	Stratford	Wynnewood (E)
SOURCE OF SUPPLY		City Lake	Ground Water	Wiley Post Lake	Ground Water	Ground Water City Lake	Ground Water	Arbuckle Lake
DATE OF ANALYSIS		2-79	6-78	6-78	6-78	8-78	6-78	8-78
PARAMETERS	UNIT							
Total Hardness	mg/L	129	523	154	165	98	228	171
Total Alkalinity	mg/L	207	787	166	438	119	317	146
Chloride	mg/L	23	72	15	41	14	14	63
Sulfate	mg/L	28	145	55	24	26	11	20
Fluoride	mg/L	0.24	0.5	0.16	0.46	0.25	0.19	0.22
Dissolved Solids	mg/L	183	1024	309	540	210	361	298
pH	SU	8	7.5	7.3	7.8	7.8	7.6	7.7
Sodium	mg/L	12	90	34	140	18	40	40
Nitrite-Nitrate	mg/L	0.1	0.1	0.2	4.2	0.4	2.1	0.2
Iron	µg/L	46	1210	110	400	120	460	110
Manganese	µg/L	8	470	70	20	<20	< 20	<20
Silver	µg/L	< 2	3	<2	< 2	<2	2	< 2
Cadmium	µg/L	<1	1	<1	<1	<1	<1	<1
Chromium	µg/L	11	19	<5	12	16	11	<5
Copper	µg/L	14	5	59	43	16	53	41
Lead	µg/L	18	22	9	6	9	11	7
Zinc	µg/L	6	39	8	36	7	49	21
Barium	µg/L	100	150	200	320	250	640	140
Arsenic	µg/L	<2	< 1	<1	3	<1	<1	<1
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	ND	<0.5	0.6	<0.5	<0.5

(A) Serves Elmore City Rural Water Corp.
(B) Serves RWD 2.
(C) Serves RWD 2.
(D) Serves RWD 1 & 4.
(E) Serves Wynnewood Rural Water Corp.

GRADY CO.

CITY		Alex	Bradley	Chickasha (A)	Minco	RWD 1	RWD 2	Rush Springs	Tuttle	Verden
SOURCE OF SUPPLY		Ground Water	Ground Water	Ft Cobb Lake	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ft Cobb Lake
DATE OF ANALYSIS		2-79	2-79	10-77	2-79	2-79	2-79	2-79	2-79	1-79
PARAMETERS	UNIT									
Total Hardness	mg/L	563	451	219	326	500	945	393	333	469
Total Alkalinity	mg/L	500	434	142	224	297	170	204	151	356
Chloride	mg/L	32	22	18	98	18	33	30	29	25
Sulfate	mg/L	91	25	113	280	209	755	119	77	102
Fluoride	mg/L	0.28	0.46	0.32	0.35	0.41	0.25	0.26	0.24	0.41
Dissolved Solids	mg/L	661	485	359	785	683	1495	496	515	550
pH	SU	7.4	7.5	8.1	8.1	7.4	7.3	7.4	6.9	7.5
Sodium	mg/L	37	35	27	152	46	84	22	30	34
Nitrite-Nitrate	mg/L	0.5	0.2	0.2	0.1	2.4	1.3	3.9	—	8.5
Iron	µg/L	100	<100	<100	<100	<100	<100	<100	180	99
Manganese	µg/L	160	510	< 10	30	<20	<20	<20	5	6
Silver	µg/L	2	1	< 2	20	3	<1	2	2	<2
Cadmium	µg/L	1	<1	<1	1	1	2	2	2	1
Chromium	µg/L	18	16	9	19	19	17	16	15	15
Copper	µg/L	5	125	5	3	7	6	9	44	28
Lead	µg/L	31	34	< 5	17	29	39	39	20	44
Zinc	µg/L	410	125	9	<0.5	32	57	210	35	8
Barium	µg/L	320	230	100	100	100	<100	140	230	150
Arsenic	µg/L	5	< 2	<1	<2	< 2	< 2	<2	< 2	<1
Selenium	µg/L	<1	<1	<1	<1	1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Serves Norge Water Corp., RWD 6

JEFFERSON CO.

CITY		Ringling (A)	Ryan	Waurika (B)
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		9-77	10-77	10-77
PARAMETERS	UNIT			
Total Hardness	mg/L	7	431	454
Total Alkalinity	mg/L	494	423	361
Chloride	mg/L	19	69	172
Sulfate	mg/L	127	52	124
Fluoride	mg/L	1.6	0.64	0.35
Dissolved Solids	mg/L	781	641	858
pH	SU	9.1	7.5	7.7
Sodium	mg/L	261	66	110
Nitrite-Nitrate	mg/L	<0.1	4.2	1.1
Iron	µg/L	<100	<100	<100
Manganese	µg/L	<10	<10	<10
Silver	µg/L	3	3	5
Cadmium	µg/L	<1	<1	<1
Chromium	µg/L	8	<5	5
Copper	µg/L	5	9	20
Lead	µg/L	7	10	18
Zinc	µg/L	6	28	44
Barium	µg/L	<100	200	100
Arsenic	µg/L	<1	<1	<1
Selenium	µg/L	<1	2	3
Mercury	µg/L	<0.5	<0.5	<0.5

(A) Serves Cornish Utility Corp.
(B) Serves Hastings, RWD 1

LOVE CO.

CITY		Leon RWD 1	Marietta	Thackerville
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		3-78	1-78	3-78
PARAMETERS	UNIT			
Total Hardness	mg/L	144	20	—
Total Alkalinity	mg/L	159	370	—
Chloride	mg/L	195	35	—
Sulfate	mg/L	45	62	—
Fluoride	mg/L	0.12	0.51	0.22
Dissolved Solids	mg/L	223	453	—
pH	SU	7.6	9.2	—
Sodium	mg/L	17	190	207
Nitrite-Nitrate	mg/L	1.3	0.5	0.6
Iron	µg/L	760	240	190
Manganese	µg/L	10	10	10
Silver	µg/L	<2	< 2	< 2
Cadmium	µg/L	<1	1	2
Chromium	µg/L	15	10	15
Copper	µg/L	6	90	3
Lead	µg/L	9	8	<5
Zinc	µg/L	135	33	2
Barium	µg/L	50	60	<50
Arsenic	µg/L	1	1	1
Selenium	µg/L	3	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5

MARSHALL CO.

CITY		Kelly	Kingston	Madill (A)	Marshall (B)
SOURCE OF SUPPLY		Ground Water	Ground Water	City Lake	Oteka Lake
DATE OF ANALYSIS		9-77	9-77	3-79	3-79
PARAMETERS	UNIT				
Total Hardness	mg/L	5	5	134	189
Total Alkalinity	mg/L	201	440	95	112
Chloride	mg/L	6	7	7	8
Sulfate	mg/L	11	32	37	77
Fluoride	mg/L	0.22	0.7	0 88	0.27
Dissolved Solids	mg/L	272	564	186	233
pH	SU	9.1	9	7.2	8
Sodium	mg/L	106	220	15	11
Nitrite-Nitrate	mg/L	< 1	0 1	0 2	0.1
Iron	µg/L	< 100	< 100	255	36
Manganese	µg/L	< 10	< 10	7	4
Silver	µg/L	< 2	2	< 2	< 2
Cadmium	µg/L	< 1	< 1	1	2
Chromium	µg/L	11	< 5	10	8
Copper	µg/L	23	37	6	8
Lead	µg/L	< 5	7	9	13
Zinc	µg/L	34	70	26	11
Barium	µg/L	< 100	< 100	< 100	< 100
Arsenic	µg/L	< 1	< 1	< 1	< 1
Selenium	µg/L	< 1	< 1	< 1	< 1
Mercury	µg/L	0.7	< 0.5	< 0.5	< 0.5

(A) Serves Oakland Public Works Auth
(B) Serves Little City, McBride

MURRAY CO.

CITY		Arbuckle (A)	Davis (B)	Sulphur (C)
SOURCE OF SUPPLY		Arbuckle Lake	Arbuckle Lake	Ground Water
DATE OF ANALYSIS		N/A	3-79	6-78
PARAMETERS	UNIT			
Total Hardness	mg/L		170	331
Total Alkalinity	mg/L		137	315
Chloride	mg/L		60	5
Sulfate	mg/L		19	13
Fluoride	mg/L		0.23	0.22
Dissolved Solids	mg/L		293	335
pH	SU		7.8	7.4
Sodium	mg/L		26	8
Nitrite-Nitrate	mg/L		0 1	< 0.1
Iron	µg/L		35	190
Manganese	µg/L		9	< 20
Silver	µg/L		< 2	< 2
Cadmium	µg/L		< 1	1
Chromium	µg/L		7	< 5
Copper	µg/L		45	30
Lead	µg/L		8	15
Zinc	µg/L		14	21
Barium	µg/L		< 100	240
Arsenic	µg/L		< 2	< 1
Selenium	µg/L		< 1	< 1
Mercury	µg/L		1.1	< 0 5

(A) Serves Dougherty
(B) Serves West Davis Rural Water Corp
(C) Serves Buckhorn Rural Water Corp., RWD 1

STEPHENS CO.

CITY		Adams RWD 1	Comanche	Duncan	Loco RWD 4 (A)	Marlow	Meridian RWD 3	Verden-Alma RWD 1
SOURCE OF SUPPLY		Ground Water	Comanche Lake	City Lakes*	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		12-78	2-79	2-79	7-78	3-77	7-78	7-78
PARAMETERS	UNIT							
Total Hardness	mg/L	259	110	248	—	—	157	—
Total Alkalinity	mg/L	212	110	131	—	—	363	—
Chloride	mg/L	14	17	55	—	—	46	—
Sulfate	mg/L	47	11	102	—	—	46	—
Fluoride	mg/L	1.6	0.21	0 33	—	0 25	0.60	—
Dissolved Solids	mg/L	332	145	346	—	—	562	—
pH	SU	7 6	7.7	8 5	—	—	7 6	—
Sodium	mg/L	15	23	39	—	—	145	—
Nitrite-Nitrate	mg/L	3.1	0 1	0.1	0.5	—	2 2	0 6
Iron	µg/L	78	865	625	—	—	<100	—
Manganese	µg/L	2	22	9	—	—	< 20	—
Silver	µg/L	< 2	< 2	< 2	—	3	2	—
Cadmium	µg/L	1	1	< 1	—	3	< 1	—
Chromium	µg/L	7	18	20	—	12	11	—
Copper	µg/L	13	5	3	—	—	7	—
Lead	µg/L	< 2	9	14	—	22	11	—
Zinc	µg/L	120	170	7	—	—	78	—
Barium	µg/L	<100	140	180	<100	<2000	100	<100
Arsenic	µg/L	3	< 2	< 2	—	2	2	—
Selenium	µg/L	2	< 1	2	—	1	< 1	—
Mercury	µg/L	<0.5	<0.5	<0 5	—	<0.5	0 6	—

(A) Serves Loco
*City lakes include Humphreys, Clean Clear Lake & Fuqua Lake

SOUTHWEST PLANNING REGION

BECKHAM CO.

CITY		Dehli (A)	Elk City	Erick	RWD 1 (B)	RWD 2 (C)	Sayre	Texola
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		11-78	7-77	1-79	8-79	11-78	7-77	3-77
PARAMETERS	UNIT							
Total Hardness	mg/L	340	355	464	307	211	355	2292
Total Alkalinity	mg/L	267	206	248	216	205	209	248
Chloride	mg/L	29	27	61	76	39	13	229
Sulfate	mg/L	78	158	229	141	19	150	1868
Fluoride	mg/L	0.75	0.25	0.48	—	0.28	0.32	—
Dissolved Solids	mg/L	454	496	673	589	294	501	3553
pH	SU	7.3	7.37	7.5	7.4	7.3	7.63	7.3
Sodium	mg/L	34	25	55	—	25	34	—
Nitrite-Nitrate	mg/L	9.7	5.2	6.1	8.9	6	4.8	8.7
Iron	µg/L	49	<200	130	<100	93	<200	—
Manganese	µg/L	3	<20	9	<20	7	<20	—
Silver	µg/L	2	3	2	—	<2	4	—
Cadmium	µg/L	1	1	4	—	4	<1	—
Chromium	µg/L	8	40	8	—	8	<10	—
Copper	µg/L	12	108	6	—	32	7	—
Lead	µg/L	9	<5	14	—	12	13	—
Zinc	µg/L	70	85	250	—	1600	85	—
Barium	µg/L	214	100	<100	—	429	<100	—
Arsenic	µg/L	<1	<1	<1	—	1	2	—
Selenium	µg/L	1	<1	2	—	<1	<1	48
Mercury	µg/L	<0.5	<0.5	<0.5	—	<0.5	<0.5	—

(A) Serves Carter PWA
(B) Serves Sentinel, Carter, Rocky, Hicks Mountain
(C) Serves Sweetwater

CADDO CO.

CITY		Anadarko	Apache	Binger	Bridgeport	Carnegie	Cement	Cyril	Eakly	Fort Cobb
SOURCE OF SUPPLY		Ft. Cobb Lake	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		9-77	9-77	9-77	9-77	9-77	7-78	3-79	9-77	9-77
PARAMETERS	UNIT									
Total Hardness	mg/L	202	266	170	337	286	189	564	191	269
Total Alkalinity	mg/L	127	267	172	293	216	191	214	200	160
Chloride	mg/L	15	5	6	10	14	71	135	4	8
Sulfate	mg/L	106	28	18	108	87	432	208	7	104
Fluoride	mg/L	0.3	0.2	0.35	0.50	0.15	—	19	0.25	0.35
Dissolved Solids	mg/L	300	312	246	474	403	1000	784	229	391
pH	SU	7.7	7.5	7.7	7.3	7.3	7.9	7.7	7.6	7.6
Sodium	mg/L	25	15	17	45	18	—	36	14	12
Nitrite-Nitrate	mg/L	0.2	0.1	1.5	6.6	2.6	0.1	3.5	2.0	5.5
Iron	µg/L	<100	<100	100	<100	270	600	68	<100	<100
Manganese	µg/L	<10	<10	<10	<10	10	40	7	<10	<10
Silver	µg/L	3	1	1	3	3	—	3	2	4
Cadmium	µg/L	<1	1	1	2	<1	—	2	<1	<1
Chromium	µg/L	<5	10	15	10	<10	—	13	<10	<10
Copper	µg/L	5	5	8	6	160	—	60	35	59
Lead	µg/L	5	20	10	11	17	—	30	6	14
Zinc	µg/L	20	980	250	360	90	—	49	780	24
Barium	µg/L	<100	100	100	100	<100	—	120	100	<100
Arsenic	µg/L	<1	<1	5	3	8	—	<1	20	4
Selenium	µg/L	<1	5	7	2	1	—	3	<1	<1
Mercury	µg/L	<0.5	1.4	<0.5	1.0	<0.5	—	<0.5	0.7	<0.5

CADDO CO.
Continued

CITY		Gracemont	Hinton	Hydro	Lookeba RWD 1	RWD 1	RWD 3 (A)	Washita
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Fort Cobb
DATE OF ANALYSIS		3-79	3-79	9-77	9-77	3-79	3-79	9-77
PARAMETERS	UNIT							
Total Hardness	mg/L	266	236	240	247	242	323	158
Total Alkalinity	mg/L	160	302	219	212	203	223	35
Chloride	mg/L	19	23	17	3	16	21	18
Sulfate	mg/L	54	54	37	50	56	92	155
Fluoride	mg/L	0.22	0.15	0.2	0.3	0.26	0.14	0.30
Dissolved Solids	mg/L	346	406	353	326	343	429	307
pH	SU	7.7	7.5	7.4	7.4	7	7	10.2
Sodium	mg/L	<10	61	26	11	12	25	23
Nitrite-Nitrate	mg/L	9.7	0.7	8.0	1.9	1.1	3	<0.1
Iron	µg/L	64	60	<100	<100	41	46	<100
Manganese	µg/L	3	3	<10	<10	3	3	<10
Silver	µg/L	<2	<2	2	3	2	<2	3
Cadmium	µg/L	<1	1	<1	<1	<1	1	<1
Chromium	µg/L	14	15	<10	<10	14	16	<10
Copper	µg/L	52	13	6	26	100	36	3
Lead	µg/L	14	14	15	17	13	12	11
Zinc	µg/L	150	26	40	60	12	27	10
Barium	µg/L	290	280	400	200	170	300	<100
Arsenic	µg/L	<1	<1	7	10	3	<1	<1
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	1.4	<1.2	0.5	<0.5	<0.5

(A) Serves Gotebo

COMANCHE CO.

CITY		Cache	Chattanooga	CKT Rural Water Assoc. (A)	Elgin	Faxon	Fletcher	Geronimo	Indiahoma	Lawton (B)
SOURCE OF SUPPLY		Ground Water	Ground Water	Tom Steed	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	City Lake
DATE OF ANALYSIS		5-77	5-77	5-77	3-79	5-77	7-78	6-79	1-79	3-79
PARAMETERS	UNIT									
Total Hardness	mg/L	36	316	262	286	614	1020	135	10	161
Total Alkalinity	mg/L	134	256	244	248	338	163	356	318	123
Chloride	mg/L	74	195	98	1	413	24	475	25	28
Sulfate	mg/L	15	28	25	17	111	903	166	65	34
Fluoride	mg/L	2.5	0.35	0.3	0.18	0.33	0.41	7.97	7.43	0.8
Dissolved Solids	mg/L	—	—	—	299	—	1598	1415	522	234
pH	SU	8.6	7.4	7.3	7.4	7.2	7.4	7.7	8.7	7.9
Sodium	mg/L	104	135	76	11	290	28	490	303	14
Nitrite-Nitrate	mg/L	0.1	10.8	0.6	4.4	8.9	7.9	1.5	0.2	0.1
Iron	µg/L	<250	730	<250	130	<250	280	100	101	56
Manganese	µg/L	<10	30	<10	3	<10	<20	6	2	4
Silver	µg/L	2	5	2	<2	7	4	<2	<2	<2
Cadmium	µg/L	1	1	1	1	3	<1	2	1	<1
Chromium	µg/L	10	14	14	12	13	9	17	8	10
Copper	µg/L	—	—	—	7	—	39	35	2	7
Lead	µg/L	7	39	10	12	15	30	16	11	17
Zinc	µg/L	—	—	—	225	—	745	405	8	5
Barium	µg/L	200	500	600	580	700	150	140	<100	16
Arsenic	µg/L	4	<1	<1	<1	<1	<1	<1	6	<1
Selenium	µg/L	<1	2	<1	<1	4	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Purchases water from Snyder, Kiowa County
(B) Serves RWD 1, Medicine Park Public Works

CITY		COMANCHE CO. Continued: RWD 2	RWD 3	Sterling	COTTON CO.: Devol	Randlett RWD 1	RWD 1	RWD 2	Temple	Walters RWD 2
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	City Lake	Ground Water City Lake
DATE OF ANALYSIS		3-79	3-79	3-79	1-79	10-77	4-79	1-79	1-79	10-77
PARAMETERS	UNIT									
Total Hardness	mg/L	293	154	435	286	236	314	116	192	100
Total Alkalinity	mg/L	231	168	253	323	228	301	141	164	100
Chloride	mg/L	14	12	3	17	18	206	10	58	4
Sulfate	mg/L	21	15	168	22	17	28	6	72	8
Fluoride	mg/L	0 21	0 25	0 3	1	0.26	0.51	0 34	0.42	0.30
Dissolved Solids	mg/L	339	313	57	404	340	778	293	405	232
pH	SU	7 5	7.7	7 7	7.6	8	7 1	7.5	7 4	7.3
Sodium	mg/L	21	49	32	58	24	19	36	66	34
Nitrite-Nitrate	mg/L	0 7	9.4	2.3	7	7.7	5.6	8	0.7	6
Iron	µg/L	74	57	62	90	140	<100	68	370	<100
Manganese	µg/L	3	3	3	44	<10	<20	<2	130	<10
Silver	µg/L	<2	<2	<2	<2	2	<20	<2	<2	<2
Cadmium	µg/L	1	<1	1	1	<1	<2	<1	1	<1
Chromium	µg/L	15	8	18	6	<5	12	<5	<5	<5
Copper	µg/L	7	22	46	19	6	150	16	29	30
Lead	µg/L	11	26	12	6	5	19	9	9	8
Zinc	µg/L	9	115	25	20	18	390	55	70	230
Barium	µg/L	130	480	120	100	10	780	500	200	<100
Arsenic	µg/L	<1	<1	<1	<1	<1	<2	<1	<1	<1
Selenium	µg/L	<1	<1	3	1	1	<1	<1	<1	<1
Mercury	µg/L	<0 5	<0.5	<0.5	<0 5	<0.5	<0.5	<0.5	<0.5	<0.5

CITY		CUSTER CO.: Clinton (A)	Custer City (B)	Foss	Thomas	Weatherford
SOURCE OF SUPPLY		City Lake	Ground Water	Foss Res	Ground Water	Ground Water
DATE OF ANALYSIS		4-77	1-79	1-79	1-79	1-79
PARAMETERS	UNIT					
Total Hardness	mg/L	240	208	263	357	243
Total Alkalinity	mg/L	189	200	32	288	129
Chloride	mg/L	19	7	13	32	4
Sulfate	mg/L	82	28	357	142	101
Fluoride	mg/L	0.4	0.15	0 11	0 26	0.41
Dissolved Solids	mg/L	368	355	1092	544	318
pH	SU	8.1	7.7	7.2	7 7	7.9
Sodium	mg/L	—	20	57	60	<10
Nitrite-Nitrate	mg/L	0.1	5.3	<0.1	1.5	4.3
Iron	µg/L	<0.1	270	270	360	2500
Manganese	µg/L	<0.01	<20	<20	<20	40
Silver	µg/L	.001	<2	<2	<2	<2
Cadmium	µg/L	.001	<2	<2	<2	<2
Chromium	µg/L	.013	<5	<5	<5	<5
Copper	µg/L	—	9	26	16	11
Lead	µg/L	.009	7	10	14	14
Zinc	µg/L	—	120	<5	20	1600
Barium	µg/L	0.13	143	<100	143	143
Arsenic	µg/L	.001	1	<1	2	27
Selenium	µg/L	.001	<1	<1	2	<1
Mercury	µg/L	<.0005	<0.5	<0 5	<0.5	<0 5

(A) Serves Arapaho, Butler PWA
(B) Will Serve Proposed RWD 3

CITY		GREER CO.: Centralvue (A)	Granite	Mangum (B)	Thirsty	Willow
SOURCE OF SUPPLY		Duke	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS			4-77	4-77	11-78	4-79
PARAMETERS	UNIT					
Total Hardness	mg/L		198	148	130	182
Total Alkalinity	mg/L		204	119	134	157
Chloride	mg/L		11	30	14	11
Sulfate	mg/L		27	18	15	10
Fluoride	mg/L		0.4	0 2	0.6	0.47
Dissolved Solids	mg/L		285	211	222	268
pH	SU		7 9	7.8	7 3	7.5
Sodium	mg/L		—	—	16	13
Nitrite-Nitrate	mg/L		8 45	8.45	7 3	11
Iron	µg/L		<100	360	70	340
Manganese	µg/L		<10	<10	2	7
Silver	µg/L		4	3	<2	<2
Cadmium	µg/L		1	1	1	1
Chromium	µg/L		19	13	6	6
Copper	µg/L		—	—	13	53
Lead	µg/L		9	12	7	12
Zinc	µg/L		—	—	55	465
Barium	µg/L		180	140	143	357
Arsenic	µg/L		<1	3	1	4
Selenium	µg/L		<1	<1	<1	<1
Mercury	µg/L		0 6	<0.5	<0.5	<0.5

(A) Purchases water from Duke, Jackson Co.
(B) Serves Reed Water Corporation & Hester Water Corporation

CITY		HARMON CO.: Harmon County (A)	Hollis	JACKSON CO.: Altus (A)	Duke (B)	Eldorado (C)	Jackson Co. Water Company (D)
SOURCE OF SUPPLY		Ground Water	Ground Water	Tom Steed Lake	Ground Water	Harmon	Ground Water
DATE OF ANALYSIS		9-77	10-77	4-77	4-77	N/A	4-77
PARAMETERS	UNIT						
Total Hardness	mg/L	263	227	486	251		148
Total Alkalinity	mg/L	228	234	137	217		129
Chloride	mg/L	16	11	210	14		27
Sulfate	mg/L	68	41	98	13		21
Fluoride	mg/L	0.43	0.54	0 4	0 4		0 5
Dissolved Solids	mg/L	498	390	671	283		222
pH	SU	7.4	7 5	8	7 9		7.7
Sodium	mg/L	36	38	—	—		—
Nitrite-Nitrate	mg/L	8.2	9.5	4.7	9.7		2.2
Iron	µg/L	<100	<100	<100	<100		<100
Manganese	µg/L	<10	<10	<10	<10		<10
Silver	µg/L	3	2	4	4		4
Cadmium	µg/L	<1	<1	3	1		1
Chromium	µg/L	<5	<5	27	17		20
Copper	µg/L	5	57	—	—		—
Lead	µg/L	8	10	12	14		4
Zinc	µg/L	44	42	—	—		—
Barium	µg/L	<100	<100	300	260		<100
Arsenic	µg/L	<1	<1	<1	3		1
Selenium	µg/L	1	<1	<1	1		1
Mercury	µg/L	<0 5	<0.5	<0 5	<0.5		<0.5

Harmon Co.:
(A) Serves Gould, El Dorado, Jackson Co., Arnett School

Jackson Co.:
(A) Serves Blair Public Works Authority, Olustee Public Works Authority
(B) Serves Centralvue Water Corp., Grant County
(C) Purchases water from Harmon County Water Corporation
(D) Serves Martha, Headrick

KIOWA CO.

CITY		Gotebo (A)	Hobart	Lone Wolfe	Mountain Park	Mountain View	Roosevelt	Snyder
SOURCE OF SUPPLY		Ground Water	City Lake	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water Tom Steed Lake
DATE OF ANALYSIS		N/A	4-79	4-79	9-77	9-77	12-78	9-77
PARAMETERS	UNIT							
Total Hardness	mg/L		210	411	279	225	476	359
Total Alkalinity	mg/L		26	299	390	263	460	347
Chloride	mg/L		11	48	154	12	72	99
Sulfate	mg/L		277	56	92	23	167	107
Fluoride	mg/L		0.19	0 67	0.30	0 30	0.36	0.30
Dissolved Solids	mg/L		496	580	795	305	897	683
pH	SU		6.9	7.1	7.5	7.5	7.3	7.3
Sodium	mg/L		59	45	190	26	145	107
Nitrite-Nitrate	mg/L		0.1	19	3.4	1.2	8.2	1.1
Iron	µg/L		240	2200	<100	<100	925	<100
Manganese	µg/L		<20	20	<10	<10	6	<10
Silver	µg/L		<2	<2	4	<2	<2	4
Cadmium	µg/L		2	<2	<1	<1	3	<1
Chromium	µg/L		16	19	<5	<5	11	<5
Copper	µg/L		<40	50	7	14	10	23
Lead	µg/L		20	29	13	11	20	17
Zinc	µg/L		80	100	50	20	2500	50
Barium	µg/L		110	270	300	200	214	300
Arsenic	µg/L		<2	3	1	2	2	8
Selenium	µg/L		<1	<1	5	<1	2	<1
Mercury	µg/L		<0.5	<0.5	0.7	<0.5	<0.5	<0 5

(A) Purchases water from RWD 3, Caddo Co.

ROGER MILLS CO.

CITY		Cheyenne	Hammon	Reydon	RWD 1 (A)	RWD 2 (B)
SOURCE OF SUPPLY		Tompson Lake	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		11-78	11-78	11-78	11-78	11-78
PARAMETERS	UNIT					
Total Hardness	mg/L	164	581	213	469	198
Total Alkalinity	mg/L	246	194	277	192	243
Chloride	mg/L	36	26	35	29	7
Sulfate	mg/L	19	399	21	223	2
Fluoride	mg/L	0.53	0.32	0.78	0 37	0.24
Dissolved Solids	mg/L	313	880	419	596	296
pH	SU	7.9	7.7	7.3	7.5	7.4
Sodium	mg/L	65	14	69	13	31
Nitrite-Nitrate	mg/L	<0.1	4.9	7.6	4.1	6.3
Iron	µg/L	265	180	45	70	135
Manganese	µg/L	5	6	<1	3	<1
Silver	µg/L	<2	3	<2	3	<2
Cadmium	µg/L	<1	2	2	2	2
Chromium	µg/L	8	5	8	7	7
Copper	µg/L	60	<5	21	45	9
Lead	µg/L	7	14	6	15	10
Zinc	µg/L	40	75	95	105	215
Barium	µg/L	214	<100	214	<100	500
Arsenic	µg/L	5	1	2	2	<1
Selenium	µg/L	<1	1	2	2	1
Mercury	µg/L	<0.5	<0.5	<0 5	<0.5	<0.5

(A) Serves Strong City
(B) Serves Leedy

TILLMAN CO.

CITY		Davidson	Frederick	Grandfield	Hollister	Manitou	RWD 1 (A)	Tipton
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		11-78	12-78	12-78	12-78	12-78	12-78	12-78
PARAMETERS	UNIT							
Total Hardness	mg/L	563	118	243	355	253	168	282
Total Alkalinity	mg/L	347	194	182	338	257	158	393
Chloride	mg/L	108	24	13	233	18	15	146
Sulfate	mg/L	100	38	8	123	16	<1	144
Fluoride	mg/L	0.59	0.22	0.6	0.31	0.45	0.48	0.95
Dissolved Solids	mg/L	712	293	322	896	382	250	932
pH	SU	7.4	8.1	7.6	7.6	7.4	7.4	7.2
Sodium	mg/L	75	70	17	218	43	18	156
Nitrite-Nitrate	mg/L	18	0.2	19.5	3 1	12.8	8 8	12.3
Iron	µg/L	52	61	93	5850	58	52	81
Manganese	µg/L	4	8	2	7	2	1	12
Silver	µg/L	<2	<2	<2	<2	<2	<2	<2
Cadmium	µg/L	2	1	<1	4	1	1	2
Chromium	µg/L	<5	<5	<5	<5	<5	<5	<5
Copper	µg/L	40	35	110	135	14	25	22
Lead	µg/L	15	6	6	12	7	6	14
Zinc	µg/L	56	100	10	2500	15	70	750
Barium	µg/L	200	300	200	100	200	200	<100
Arsenic	µg/L	<1	<1	<1	31	<1	<1	<1
Selenium	µg/L	3	<1	<1	3	<1	<1	90
Mercury	µg/L	<0.5	<0.5	<0.5	<0 5	<0.5	<0 5	<0.5

(A) Serves Loveland

WASHITA CO.

CITY		Bessie	Canute	Colony	Cordell	Corn	Dill City	Foss	Rocky (A)	RWD 2	Sentinel
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		1-78	4-79	9-77	4-79	12-78	4-79	4-79	N/A	N/A	9-77
PARAMETERS	UNIT										
Total Hardness	mg/L	320	398	182	280	188	351	526	—	—	380
Total Alkalinity	mg/L	288	333	162	258	214	306	549	—	—	212
Chloride	mg/L	161	17	8	6	4	24	35	—	—	14
Sulfate	mg/L	62	15	10	13	<1	17	50	—	—	148
Fluoride	mg/L	0.33	0.37	0.35	0.44	0.28	0.45	0 34	—	—	0.50
Dissolved Solids	mg/L	636	707	246	433	255	476	707	—	—	579
pH	SU	7.5	70	7.8	1	7.4	6.9	7	—	—	7.5
Sodium	mg/L	140	40	<5	20	12	32	<2	—	—	19
Nitrite-Nitrate	mg/L	0.4	6.7	4.5	6	2.2	6.2	8 4	—	—	5 9
Iron	µg/L	<40	<100	<100	<100	61	700	<100	—	—	<100
Manganese	µg/L	<20	<20	<10	<20	1	<20	<20	—	—	<10
Silver	µg/L	3	<2	<2	<2	<2	<2	56	—	—	<1
Cadmium	µg/L	<1	<2	<1	<2	1	3	2	—	—	<1
Chromium	µg/L	11	17	6	18	<5	16	16	—	—	<5
Copper	µg/L	65	230	9	<40	20	60	<40	—	—	10
Lead	µg/L	45	22	9	16	16	27	32	—	—	12
Zinc	µg/L	27	90	540	100	230	800	70	—	—	50
Barium	µg/L	100	680	200	680	286	650	490	—	—	<100
Arsenic	µg/L	<1	<2	7	4	11	<2	3	—	—	<1
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1	—	—	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	—	—	<0.5

(A) Purchases water from RWD 1, Beckham Co.

EAST CENTRAL PLANNING REGION

HASKELL CO.

CITY		Haskell (A)	Keota	Mason Oaks RWD 3	RWD 1	Stigler
SOURCE OF SUPPLY		Eufaula Lake	Strip Pits	Eufaula Lake	Eufaula Lake	Eufaula Lake
DATE OF ANALYSIS		5-78	5-77	3-79	3-79	5-77
PARAMETERS	UNIT					
Total Hardness	mg/L	134	246	140	144	67
Total Alkalinity	mg/L	44	110	93	99	30
Chloride	mg/L	72	7	70	77	9
Sulfate	mg/L	80	162	47	45	33
Fluoride	mg/L	0.12	0.30	0.47	0.45	<0.1
Dissolved Solids	mg/L	291	—	333	334	100
pH	SU	7.1	8.4	7.5	7.6	7.6
Sodium	mg/L	42	—	53	51	—
Nitrite-Nitrate	mg/L	0.1	0.2	0.1	0.2	<0.1
Iron	μg/L	560	500	110	<100	765
Manganese	μg/L	20.0	90.0	<20	<20	50
Silver	μg/L	<2	2	<20	<20	4
Cadmium	μg/L	<1	3	<2	<2	1
Chromium	μg/L	21	10	<10	<10	11
Copper	μg/L	90	—	<40	<40	—
Lead	μg/L	7	15	10	10	124
Zinc	μg/L	24	—	<40	130	—
Barium	μg/L	<100	<100	590	600	<100
Arsenic	μg/L	<1	1	<2	<2	2
Selenium	μg/L	<1	<3	<1	<1	<3
Mercury	μg/L	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Serves Kinta; Longtown RWD 1, Pittsburg Co.; Quinton, Pittsburg Co.

HUGHES CO.

CITY		Calvin	Dustin	Holdenville (A)	Stuart RWD 2	Wetumka (B)
SOURCE OF SUPPLY		Ground Water	City Lake	City Lakes	Ground Water	City Lake
DATE OF ANALYSIS		7-78	5-78	5-78	7-78	5-78
PARAMETERS	UNIT					
Total Hardness	mg/L	503	47	67	216	80
Total Alkalinity	mg/L	363	20	68	198	44
Chloride	mg/L	49	9	9	20	27
Sulfate	mg/L	56	31	24	98	29
Fluoride	mg/L	0.21	0.06	0.19	0.23	0.14
Dissolved Solids	mg/L	615	113	120	390	155
pH	SU	7	6.5	8.3	6.9	7.6
Sodium	mg/L	28	5	6	49	13
Nitrite-Nitrate	mg/L	4.4	0.3	0.1	0.1	0.1
Iron	μg/L	150	600	110	490	500
Manganese	μg/L	20	130	<10	370	<10
Silver	μg/L	3	<2	<2	<2	<2
Cadmium	μg/L	<1	<1	<1	<1	<1
Chromium	μg/L	<10	17	14	10	18
Copper	μg/L	35	26	<2	6	85
Lead	μg/L	25	<5	<5	9	5
Zinc	μg/L	125	120	13	29	25
Barium	μg/L	240	<50	<50	<100	60
Arsenic	μg/L	1	3	22	<1	<1
Selenium	μg/L	1.9	<1	<1	<1	<1
Mercury	μg/L	<0.5	<0.5	<0.5	<0.5	<0.5

(A) Serves Lamar and RWD 3

(B) Serves RWD 1.

LATIMER CO.

CITY		Red Oak (A)	RWD 3	Wilburton (B)
SOURCE OF SUPPLY		Strip Pits	Eufaula Lake	Church Lake
DATE OF ANALYSIS		3-79	N/A	3-79
PARAMETERS	UNIT			
Total Hardness	mg/L	133	—	32
Total Alkalinity	mg/L	121	—	15
Chloride	mg/L	11	—	3
Sulfate	mg/L	67	—	16
Fluoride	mg/L	0.28	—	0.43
Dissolved Solids	mg/L	253	—	77
pH	SU	8.2	—	6.8
Sodium	mg/L	31	—	<10
Nitrite-Nitrate	mg/L	0.5	—	0.1
Iron	μg/L	110	—	140
Manganese	μg/L	<20	—	<20
Silver	μg/L	<20	—	<20
Cadmium	μg/L	<20	—	<2
Chromium	μg/L	<10	—	10
Copper	μg/L	<40	—	<40
Lead	μg/L	12	—	<10
Zinc	μg/L	70	—	<40
Barium	μg/L	370	—	150
Arsenic	μg/L	<2	—	<2
Selenium	μg/L	<1	—	<1
Mercury	μg/L	<0.5	—	<0.5

(A) Serves Water Distributors Co., Inc., Leflore County.

(B) Serves RWD 1, Cowen, Panola Denman, Damon, Higgins.

LeFLORE CO.

CITY		Heavener (A)	Ouchita	Poteau Valley Improvement Authority (B)	Spiro	Talihina (C)
SOURCE OF SUPPLY		Poteau River	Ground Water	Wister Lake	City Lake	Carl Albert Lake
DATE OF ANALYSIS		3-79	5-78	5-77	5-77	5-77
PARAMETERS	UNIT					
Total Hardness	mg/L	27	62	55	69	71
Total Alkalinity	mg/L	27	72	34	40	115
Chloride	mg/L	<1	5	4	11	7
Sulfate	mg/L	26	12	22	21	32
Fluoride	mg/L	<0.06	0.13	0.1	0.1	<0.1
Dissolved Solids	mg/L	59	134	78	96	188
pH	SU	6.5	6.8	9.0	7.6	7.8
Sodium	mg/L	<10	17	—	—	—
Nitrite-Nitrate	mg/L	0.3	0.1	0.3	0.2	<0.1
Iron	μg/L	<100	860	<100	730	130
Manganese	μg/L	<20	140	<10	70	<10
Silver	μg/L	<20	<1	1	<1	2
Cadmium	μg/L	<2	<1	2	7	2
Chromium	μg/L	26	10	5	5	4
Copper	μg/L	<40	6	—	—	—
Lead	μg/L	<10	5	3	7	4
Zinc	μg/L	<40	41	—	—	—
Barium	μg/L	130	<100	<100	<100	<100
Arsenic	μg/L	<2	<1	<1	<1	<1
Selenium	μg/L	<1	<1	<3	<3	<3
Mercury	μg/L	<0.5	<0.5	<0.5	<0.5	<0.5

McINTOSH CO.

CITY		Checotah (A)	Eufaula (B)	Hanna (C)	Muskogee RWD 3 (D)	Standing Rock (E)
SOURCE OF SUPPLY		City Lake	Eufaula Lake	Ground Water	Eufaula Lake	Eufaula Lake
DATE OF ANALYSIS		3-78	3-78	3-78	3-78	N/A
PARAMETERS	UNIT					
Total Hardness	mg/L	164	112	74	148	—
Total Alkalinity	mg/L	115	64	110	140	—
Chloride	mg/L	88	40	6	87	—
Sulfate	mg/L	60	71	18	—	—
Fluoride	mg/L	0.29	0.12	0.11	0.31	—
Dissolved Solids	mg/L	347	208	137	367	—
pH	SU	8.5	6.9	7.4	8.7	—
Sodium	mg/L	71	26	28	84	—
Nitrite-Nitrate	mg/L	<0.1	0.4	0.3	0.1	—
Iron	μg/L	50	380	50	<50	—
Manganese	μg/L	<20	30	<20	<20	—
Silver	μg/L	<2	<2	<1	12	—
Cadmium	μg/L	<1	<1	<1	<1	—
Chromium	μg/L	23	28	7	20	—
Copper	μg/L	2	4	7	34	—
Lead	μg/L	9	13	<5	7	—
Zinc	μg/L	34	33	22	100	—
Barium	μg/L	70	70	80	90	—
Arsenic	μg/L	1	<1	2	<1	—
Selenium	μg/L	<1	<1	<1	<1	—
Mercury	μg/L	<0.5	<0.5	<0.5	<0.5	—

OKFUSKEE CO.

CITY		Boley RWD 1	Okemah (A)	Paden	Weleetka
SOURCE OF SUPPLY		Ground Water	Okemah Lake	Ground Water	Weleetka Lake
DATE OF ANALYSIS		4-77	11-77	4-77	11-77
PARAMETERS	UNIT				
Total Hardness	mg/L	36	111	325	52
Total Alkalinity	mg/L	20	60	299	21
Chloride	mg/L	12	29	9	26
Sulfate	mg/L	10	26	7	3
Fluoride	mg/L	0.10	0.91	0.20	0.44
Dissolved Solids	mg/L	58	119	356	201
pH	SU	6.3	8.2	7.6	7.2
Sodium	mg/L	—	20	—	15
Nitrite-Nitrate	mg/L	1.0	0.2	0.1	0.3
Iron	μg/L	<100	165	<100	525
Manganese	μg/L	<10	10	<10	65
Silver	μg/L	2	1	33	<2
Cadmium	μg/L	<1	<1	1	<1
Chromium	μg/L	25	8	20	7.5
Copper	μg/L	—	4	—	5
Lead	μg/L	<3	5	4	6
Zinc	μg/L	—	16.5	—	115
Barium	μg/L	<100	<100	200	<100
Arsenic	μg/L	1	<1	1	1
Selenium	μg/L	<1	<1	<1	<1
Mercury	μg/L	<0.5	<0.5	<0.5	<0.5

LEFLORE

(A) Serves RWD 5, Howe Water Distributors Co

(B) Serves Cameron PWA, Monroe Water Assoc. Inc., RWD 1, 2, 4, Spiro East-West Water Assoc., Northwest Water Assoc., Pocola, Howe, Bokoshe, Poteau, McCurtain, Fanshawne, LeFlore, Summerfield, Wister, Rock Island, Heavener, Panama, Shady Point, Cowlington, Tucker, Kerr Lock & Dam.

(C) Serves RWD 2, Pushmataha Co. & RWD 2, Latimer Co., RWD 3

McINTOSH

(A) Serves Shady Grove RWD 5, RWD 3, Pierce Area Dev. Corp., RWD 2, Onapa RWD, Victor RWD, 4-Man's Cove, Brushhill Village RWD.

(B) Serves RWD 6, Eufaula Utility Auth., Eufaula Enterprises, River Oaks, Eagle Bluff.

(C) Serves Vernon, (D) Serves RWD 4, Hitchita. (E) Serves Cresent Hills

OKFUSKEE

(A) Serves RWD 1, 2, Bearden, Castle, Cromwell Water District 3, Seminole Co., Okfuskee, Pharoah

PITTSBURG CO.

CITY		Crowder (A)	Kiowa (B)	Krebs	McAlester (C)	Pittsburg	Pittsburg Co. (D)	RWD 4	U.S. Naval Ammunition Depot (E)
SOURCE OF SUPPLY		City Lake	City Lake	McAlester Lake	McAlester Lake	City Lake	Eufaula Lake	Eufaula Lake	Brown Lake
DATE OF ANALYSIS		5-77	7-79	5-79	5-77	5-77	3-78	5-77	2-78
PARAMETERS	UNIT								
Total Hardness	mg/L	42	44	58	45	54	77	64	63
Total Alkalinity	mg/L	18	26	29	21	<3	59	11	51
Chloride	mg/L	6	5	5	6	5	12	21	7
Sulfate	mg/L	17	30	45	20	51	79	49	68
Fluoride	mg/L	0.08	<0.6	<0.06	0.45	0.06	0.08	0.1	0.11
Dissolved Solids	mg/L	—	119	131	—	—	131	—	88
pH	SU	8.1	6.3	7 3	9.2	4 8	9.4	7 0	8.2
Sodium	mg/L	<10	<10	<10	<10	<10	20	21	8
Nitrite-Nitrate	mg/L	<0.1	0.3	<0.5	0.3	<0.1	0.2	0.1	<0.1
Iron	µg/L	200	320	200	<200	330	90	<200	60
Manganese	µg/L	50	60	370	<10	70	<20	<10	<20
Silver	µg/L	2	<2	<2	<1	2	<2	1	<2
Cadmium	µg/L	<1	<2	3	<1	<1	<1	1	1
Chromium	µg/L	7	<10	<10	<1	3	20	7	20
Copper	µg/L	—	<40	<46	—	—	2	—	4
Lead	µg/L	16	<10	10	4	8	<5	<1	<5
Zinc	µg/L	—	<40	<40	—	—	127	—	18
Barium	µg/L	500	<100	<100	600	400	<50	500	70
Arsenic	µg/L	<1	<5	<5	<1	<1	1	<1	1
Selenium	µg/L	<1	<5	<6	<1	<1	<1	<1	<1
Mercury	µg/L	0.8	<0.5	0.6	1.3	0 9	<0.5	0 9	<0.5

(A) Serves Indianola Water Co., Canadian, Lakeside Water Company, Inc., Canadian Shores, Sam's Point.
(B) Serves RWD 11.
(C) Serves Tannehill Water Co., RWD 5, 6, 7, 9, McAlester State Prison.
(D) Serves Hartshorne Public Works Auth., Adamson Water District Co., Inc., Haileyville.
(E) Serves Savana

SEMINOLE CO.

CITY		Bowlegs-Lima RWD (A)	Cromwell	Konowa	Maud	Sasakwa	Sasakwa RWD 4	Seminole (B)	Wewoka (C)
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	City Lake
DATE OF ANALYSIS		10-77	5-78	10-77	7-77	10-77	10-77	10-77	10-77
PARAMETERS	UNIT								
Total Hardness	mg/L	12	93	398	<3	173	258	105	94
Total Alkalinity	mg/L	429	80	448	748	339	263	179	69
Chloride	mg/L	45	33	268	51	8	10	30	34
Sulfate	mg/L	81	33	39	97	48	15	53	31
Fluoride	mg/L	2	1.1	0.91	4 5	0.42	0.28	0.36	0.2
Dissolved Solids	mg/L	676	205	931	1025	420	319	338	183
pH	SU	8.8	8.0	7.5	8.9	7.2	7.3	7.7	7 6
Sodium	mg/L	250	20	185	45	95	<10	100	<10
Nitrite-Nitrate	mg/L	<0.1	0.2	0.4	0 2	<0 1	0.1	0.4	0.1
Iron	µg/L	<100	430	100	<200	850	<100	225	110
Manganese	µg/L	<10	20	<10	<10	180	15	12	<10
Silver	µg/L	<2	<2	3	2	<2	<2	<2	<2
Cadmium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	µg/L	8	18	45	<5	35	20	5	15
Copper	µg/L	9	<2	14	12	8	42	85	7
Lead	µg/L	<5	6	<5	15	<5	<5	<5	<5
Zinc	µg/L	5	25	33	19	15	49	1200	13
Barium	µg/L	<100	60	500	<100	<100	400	<100	<100
Arsenic	µg/L	<1	<1	<1	<1	<1	<1	1	<1
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5

(A) Serves Bowlegs, Lima, & New Lima.
(B) Serves Earlsboro Water District.
(C) Serves RWD 1 & 2

SEQUOYAH CO.

CITY		East Central Okla. Water Authority (A)	Muldrow	Sallisaw (B)	Sequoyah Co. Water Assoc. (C)	Sequoyah Utility
SOURCE OF SUPPLY		Tenkiller Res.	City Lake	Brush Lake	Tenkiller Res.	Tenkiller Res
DATE OF ANALYSIS		4-79	8-78	4-79	8-78	8-78
PARAMETERS	UNIT					
Total Hardness	mg/L	96	69	47	82	59
Total Alkalinity	mg/L	85	64	26	76	80
Chloride	mg/L	11	4	6	7	4
Sulfate	mg/L	10	40	14	28	12
Fluoride	mg/L	0.06	0 09	0.06	<0.06	<0 06
Dissolved Solids	mg/L	150	132	123	151	85
pH	SU	7 7	8.8	8 4	7 8	7.7
Sodium	mg/L	<10	10	10	9	6
Nitrite-Nitrate	mg/L	0.7	0 1	1	0.3	0 4
Iron	µg/L	<100	<100	<100	640	<100
Manganese	µg/L	<20	<20	<20	<20	30
Silver	µg/L	<2	<2	<2	<2	<2
Cadmium	µg/L	3	<1	4	1	<1
Chromium	µg/L	21	11	18	6	8
Copper	µg/L	<4	2	4	3	2
Lead	µg/L	10	40	17	47	8
Zinc	µg/L	<4	9	5	3	3
Barium	µg/L	<100	<100	<100	<100	<100
Arsenic	µg/L	<2	<1	<2	<1	<1
Selenium	µg/L	<1	<1	<1	<1	<1
Mercury	µg/L	<0 5	4	<0.5	<0.5	0.9

(A) Serves Core.
(B) Serves RWD 1, 3, 4 & Gans
(C) Serves Vian PWA, Box, Blackgum, McKay, Marble City, Brushy, Liberty, Short, Nicut, Maple, Long, Blue Mouse, Scott, & Atkins

NORTHEAST PLANNING REGION

ADAIR CO.

CITY		Cherry Tree RWD 1	Stilwell	Watts	Westville
SOURCE OF SUPPLY		Ground Water	Lake Carson	Lake Francis	Ground Water
DATE OF ANALYSIS		5-78	11-78	11-78	8-77
PARAMETERS	UNIT				
Total Hardness	mg/L	180	84	113	109
Total Alkalinity	mg/L	172	99	136	77
Chloride	mg/L	8	4	10	6
Sulfate	mg/L	13	15	22	<3
Fluoride	mg/L	0.19	0.07	<0 06	<0 06
Dissolved Solids	mg/L	214	123	182	153
pH	SU	7	8.4	7.9	8.0
Sodium	mg/L	<5	10	18	<5
Nitrite-Nitrate	mg/L	0.9	0.6	1.7	1 5
Iron	µg/L	<100	100	<100	<200
Manganese	µg/L	<20	30	<20	<10
Silver	µg/L	<2	<2	<2	2
Cadmium	µg/L	2	<1	<1	<1
Chromium	µg/L	9	14	12	10
Copper	µg/L	34	4	9	180
Lead	µg/L	11	33	7	6
Zinc	µg/L	95	2	12	<10
Barium	µg/L	<100	<100	<100	<100
Arsenic	µg/L	<0 1	<1	<1	<1
Selenium	µg/L	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0 5	<0.5

CHEROKEE CO.

CITY		Cinderwood	Cookson	Hulbert	Keyes RWD 2	Norwood RWD 1	Peggs	Summit	Tahlequah (A)	Tenkiller Water Inc.
SOURCE OF SUPPLY		Tenkiller	Tenkiller	Fourteen Mile Cr.	Tenkiller	Ft. Gibson Res.	Springs	Tenkiller	Illinois River	Tenkiller
DATE OF ANALYSIS		7-77	7-77	7-77	7-77	6-77	7-77	7-77	7-77	12-78
PARAMETERS	UNIT									
Total Hardness	mg/L	41	84	118	88	124	93	99	107	115
Total Alkalinity	mg/L	122	71	107	83	110	94	95	94	ND
Chloride	mg/L	13	11	9	10	14	3	4	8	37
Sulfate	mg/L	11	15	17	18	32	5	12	13	25
Fluoride	mg/L	12	0.11	0.08	0.09	0.14	0.13	0.06	1.2	<0.06
Dissolved Solids	mg/L	264	132	162	137	208	124	136	146	179
pH	SU	8.7	8.2	7.2	8.1	7 9	7.1	7.6	7.2	7 8
Sodium	mg/L	12.1	<5	7	9	15	<5	10	7	<10
Nitrite-Nitrate	mg/L	<0.1	0.3	0.2	0.2	<0 1	1.2	4	0.3	0.6
Iron	µg/L	6800	<200	<200	<200	<200	<200	<200	<200	110
Manganese	µg/L	70	10	10	10	10	10	10	10	20
Silver	µg/L	<2	<2	3	<2	3	2	<2	6	<1
Cadmium	µg/L	1	1	<1	1	<1	<1	<1	<1	2
Chromium	µg/L	45	10	15	<10	25	20	<10	20	14
Copper	µg/L	5	5	3	3	4	24	11	7	3
Lead	µg/L	8	6	<5	<5	5	7	10	<5	8
Zinc	µg/L	49	20	14	12	32	70	62	13	6
Barium	µg/L	<400	<400	<400	<400	<400	<400	<400	<400	<100
Arsenic	µg/L	13	<1	<1	<1	1	<1	<1	<1	<1
Selenium	µg/L	<1	<1	<1	<1	1	<1	<1	<1	<1
Mercury	µg/L	<0 5	<0.5	0.5	<0.5	<0 5	<0.5	<0.5	<0 5	<0.5

(A) Serves Parkhill RWD 5, Stick Ross Mtn. Water Co., Grandview RWD 3.

CRAIG CO.

CITY		Blue Jacket	Ketchum	Vinita (A)	Welch
SOURCE OF SUPPLY		Ground Water	Grand Lake	Grand Lake	Ground Water
DATE OF ANALYSIS		4-77	7-77	5-79	4-77
PARAMETERS	UNIT				
Total Hardness	mg/L	92	93	157	208
Total Alkalinity	mg/L	169	83	99	163
Chloride	mg/L	166	7	16	455
Sulfate	mg/L	27	55	47	14
Fluoride	mg/L	3.6	0.25	0.41	0.10
Dissolved Solids	mg/L	—	158	221	—
pH	SU	8.2	7 7	7.1	7.8
Sodium	mg/L	—	24	10	—
Nitrite-Nitrate	mg/L	0.8	0.9	2.6	<0.1
Iron	µg/L	<200	300	<100	<200
Manganese	µg/L	<10	20	<20	<10
Silver	µg/L	<1	3	<2	3
Cadmium	µg/L	1	<1	<2	2
Chromium	µg/L	25	10	<10	32
Copper	µg/L	—	46	<4.0	—
Lead	µg/L	5	12	16	8
Zinc	µg/L	—	435	<40	—
Barium	µg/L	<100	<100	<100	290
Arsenic	µg/L	<1	<1	<2	<1
Selenium	µg/L	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5

(A) Serves Big Cabin, RWD 1 and RWD 2

CREEK CO.

CITY		Bristow	Depew	Drumright	Mannford (A)	Mounds RWD 7	Oilton	Sapulpa (B)	Shamrock	Slick
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	City Lake	Jackson Lake	Ground Water	Sahoma Lake	Ground Water	Ground Water
DATE OF ANALYSIS		9-77	9-77	6-78	6-78		9-77	9-77	6-78	9-77
PARAMETERS	UNIT									
Total Hardness	mg/L	220	208	353	103		82	29	165	359
Total Alkalinity	mg/L	239	234	307	62		201	45	167	283
Chloride	mg/L	20	6	10	58		16	7	22	156
Sulfate	mg/L	10	7	81	46		121	15	11	72
Fluoride	mg/L	0.20	0 20	0 17	0.70		0.30	0.20	0.30	0.18
Dissolved Solids	mg/L	283	279	420	231		496	64	198	ND
pH	SU	7.5	7.6	7.4	7.5		8.0	6.4	7.4	7.3
Sodium	mg/L	25	18	18	21		114	13	14	91
Nitrite-Nitrate	mg/L	0 4	0.2	<0.1	<0.1		<0.1	<0.7	<0 1	<0.1
Iron	µg/L	<100	<100	770	160		<100	100	2300	900
Manganese	µg/L	<10	<10	20	<20		20	50	440	350
Silver	µg/L	<2	4	<2	<2		2	<2	<2	4
Cadmium	µg/L	<1	<1	<2	<1		<1	<1	2	<1
Chromium	µg/L	20	10	5	<5		<5	<5	<5	<5
Copper	µg/L	<3	10	25	20		2	31	15	12
Lead	µg/L	<5	25	20	8		6	<5	25	9
Zinc	µg/L	10	90	700	23		50	40	1300	470
Barium	µg/L	<100	200	<100	<100		<100	<100	110	<100
Arsenic	µg/L	2	<1	<1	<1		<1	<1	15	<1
Selenium	µg/L	1	1	<1	<1		<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0 5	<0.5

(A) Serves RWD 5, RWD 2 Inc. Pawnee Co.
(B) Serves Glenpool, Kiefer, RWD 1, 2, 3, 4, Sapulpa Rural Water Corp., & RWD 2 Tulsa County

DELAWARE CO.

CITY		Colcord	Durett	Grove	Jay	Kansas	Oaks
SOURCE OF SUPPLY		Ground Water	Grand Lake	Grand Lake	Grand Lake	Ground Water	Ground Water
DATE OF ANALYSIS		9-77	5-79	9-77	9-77	9-77	8-77
PARAMETERS	UNIT						
Total Hardness	mg/L	137	133	108	96	136	44
Total Alkalinity	mg/L	126	93	60	89	191	177
Chloride	mg/L	<3	13	12	8	63	41
Sulfate	mg/L	5	36	45	19	17	19
Fluoride	mg/L	0.07	0.16	0.14	0.10	0.90	3
Dissolved Solids	mg/L	192	196	193	141	286	285
pH	SU	7 2	7.5	7.4	7 8	8.2	7.7
Sodium	mg/L	5.0	14	8.0	6.0	63	93
Nitrite-Nitrate	mg/L	2 4	1 8	0.7	0 2	<0.1	0 1
Iron	µg/L	<100	360	150	100	100	170
Manganese	µg/L	<10	<20	10.0	10 0	<10	<10
Silver	µg/L	2	<2	<2	<2	2	1
Cadmium	µg/L	<1	<2	<1	<1	<1	1
Chromium	µg/L	<10	10	10	10	15	10
Copper	µg/L	25	<40	7	73	160	75
Lead	µg/L	10	16	8	7	10	<5
Zinc	µg/L	60	<40	320	37	80	60
Barium	µg/L	<100	<100	<100	<100	<100	<100
Arsenic	µg/L	<1	<2	<1	<1	<1	<1
Selenium	µg/L	<1	<1	2	1	<1	<1
Mercury	µg/L	<0.5	<0 5	<0.5	<0 5	<0.5	<0.5

MAYES CO.

CITY		Adair	Craig	Disney RWD 3	Grand Lake Towne	Lake Hudson RWD 6	Langley	Locust Grove	RWD 3	Salina	Spavinaw
SOURCE OF SUPPLY		Quarry Pit	Ground Water	Grand Lake	Grand Lake	Hudson Lake	Hudson Lake	Ground Water	Grand Lake	Hudson Lake	Spavinaw Lake
DATE OF ANALYSIS		5-78	7-78	5-79	5-79	5-79	9-79	5-79	10-78	5-79	5-79
PARAMETERS	UNIT										
Total Hardness	mg/L	173	152	129	131	145	93	121	124	131	83
Total Alkalinity	mg/L	124	160	86	99	84	54	81	87	81	81
Chloride	mg/L	9	7	13	12	16	6	15	12	12	5
Sulfate	mg/L	62	<1	42	38	68	42	40	69	57	15
Fluoride	mg/L	0 15	<0.06	0 17	0.10	0 09	0 15	0 15	0.13	0.07	<0 06
Dissolved Solids	mg/L	240	206	206	188	230	176	193	178	197	196
pH	SU	7 2	7.2	7.1	7.1	6.9	7.4	6 9	7 8	7 1	7.2
Sodium	mg/L	12	<10	<10	10	10	9	10	14	10	<10
Nitrite-Nitrate	mg/L	0.3	0.7	2.1	2.2	2.1	0.7	1.7	0.6	1.8	0.8
Iron	µg/L	140	140	120	<100	<100	340	180	<100	<100	110
Manganese	µg/L	<20	<20	<20	<20	<20	20	50	20	<20	<20
Silver	µg/L	<2	2	<2	<2	<2	<2	<2	<2	<2	<2
Cadmium	µg/L	2	1	3	3	<2	<1	3	<1	<2	3
Chromium	µg/L	10	11	10	10	12	10	10	11	10	11
Copper	µg/L	<40	22	<40	<40	<40	40	<40	8	<40	<40
Lead	µg/L	16	13	12	12	16	7	<10	9	12	16
Zinc	µg/L	110	33	140	300	<40	80	<40	290	130	140
Barium	µg/L	<100	100	<100	<100	<100	<100	<100	<100	<100	<100
Arsenic	µg/L	<2	<1	<2	<2	<2	<1	<2	<1	<2	<2
Selenium	µg/L	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
Mercury	µg/L	<0 5	<0 5	<0 5	<0.5	<0 5	<0.5	<0.5	<0 5	<0.5	<0.5

MUSKOGEE CO.

CITY		Boynton	Braggs	Ft. Gibson (A)	Haskell	Muskogee (B)	Porum	RWD 3	Warner
SOURCE OF SUPPLY		City Lake	Ground Water	Grand River	Ground Water	Ft. Gibson Lake	Eufaula Lake	Eufaula Lake	Jacob Johnston Lake
DATE OF ANALYSIS		10-78	6-78	5-79	6-78	5-79	5-79	3-78	5-79
PARAMETERS	UNIT								
Total Hardness	mg/L	120	23	131	159	102	138	148	27
Total Alkalinity	mg/L	55	55	85	189	54	88	140	47
Chloride	mg/L	18	8	29	35	31	77	87	8
Sulfate	mg/L	78	6	40	9	39	47	—	20
Fluoride	mg/L	0.13	0.11	0.18	0 22	0.39	0.25	31	0.14
Dissolved Solids	mg/L	228	179 9	219	324 3	189	345	367	117
pH	SU	8 9	6.3	7.3	6.9	8.2	7 3	8.7	7.2
Sodium	mg/L	12	10	11	39	10	51	84	17
Nitrite-Nitrate	mg/L	0.3	1.4	1.2	3.0	1.2	0.2	0.1	1.5
Iron	µg/L	<100	<100	<100	360	100	<100	<50	400
Manganese	µg/L	<120	60 0	<20	40	<20	<2	20	30
Silver	µg/L	2	<1	<2	<1	<2	<2	12	<2
Cadmium	µg/L	1	<1	5	2	3	3	<1	3
Chromium	µg/L	<5	9	17	7	16	15	20	15
Copper	µg/L	7	22	<40	8	<40	<40	34	<40
Lead	µg/L	6	<5	14	5	19	15	7	10
Zinc	µg/L	7	13	<40	9	<40	<40	100	60
Barium	µg/L	<100	<100	<100	250	<100	100	90	<100
Arsenic	µg/L	<1	<1	<2	6	<2	<2	<1	<2
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0 5	<0.5	<0.5	<0.5	<0 5	<0.5	<0.5

(A) Serves RWD 4 & 7.
(B) Serves RWD 1, 2, 5, 7, Taft, Porter P W.A. Wagoner Co.

NOWATA CO.

CITY		Delaware	Lenapah	New Alluwe & RWD 1	Nowata (A)
SOURCE OF SUPPLY		Verdigris River	Verdigris River	Oolagah River	Verdigris River
DATE OF ANALYSIS		6-79	7-77	7-77	7-77
PARAMETERS	UNIT				
Total Hardness	mg/L	217	126	826	145
Total Alkalinity	mg/L	63	80	87	93
Chloride	mg/L	29	15	24	21
Sulfate	mg/L	120	85	961	45
Fluoride	mg/L	0.12	0.15	0.28	0.41
Dissolved Solids	mg/L	306	229	1481	212
pH	SU	6.6	8.1	7 3	8.0
Sodium	mg/L	12	36	32	13
Nitrite-Nitrate	mg/L	1.5	0.4	0 1	0 2
Iron	µg/L	340	<200	<200	290
Manganese	µg/L	<20	40	50	<20
Silver	µg/L	<2	<2	4	<2
Cadmium	µg/L	5	<1	<1	<1
Chromium	µg/L	16	10	10	15
Copper	µg/L	<40	6	14	140
Lead	µg/L	—	5	8	18
Zinc	µg/L	170	58	100	120
Barium	µg/L	150	<100	100	<100
Arsenic	µg/L	<2	<1	<1	3
Selenium	µg/L	<1	<1	3	<1
Mercury	µg/L	0 8	<0 5	<0 5	<0.5

(A) Serves Elm Bend, RWD 2, 3, 5 and 6

OKMULGEE CO.

CITY		Beggs	Henryetta (A)	Okmulgee (B)
SOURCE OF SUPPLY		City Lake	City Lake	City Lake
DATE OF ANALYSIS		8-78	8-78	9-77
PARAMETERS	UNIT			
Total Hardness	mg/L	68	62	63
Total Alkalinity	mg/L	42	21	50
Chloride	mg/L	22	8	33
Sulfate	mg/L	36	50	17
Fluoride	mg/L	0 1	0.11	0.16
Dissolved Solids	mg/L	140	114	164
pH	SU	7.7	8.1	8.9
Sodium	mg/L	12	8	18
Nitrite-Nitrate	mg/L	0.1	0.4	0.1
Iron	µg/L	250	320	<100
Manganese	µg/L	20	< 20	< 10
Silver	µg/L	< 2	< 2	< 2
Cadmium	µg/L	<1	< 1	1
Chromium	µg/L	11	11	10
Copper	µg/L	3	4	1
Lead	µg/L	5	36	< 5
Zinc	µg/L	3	<1	< 10
Barium	µg/L	< 100	<100	<100
Arsenic	µg/L	< 1	<1	< 1
Selenium	µg/L	< 1	<1	< 1
Mercury	µg/L	< 0.5	< 0 5	< 0 5

(A) Serves Dewar, RWD 1, 3, & 5, Salem Rural Water Corp., Dripping Springs Rural Water Corp.
(B) Serves RWD 2, 4, 6, 7, Southeast Okmulgee Rural Water Corp., M & L Water District Inc.

OSAGE CO.

CITY		Avant	Barnsdall (A)	Burbank	Fairfax (B)	Hominy	Hulah	Osage	Pawhuska	Prue	Shidler	Wynona
SOURCE OF SUPPLY		City Lake	Waxhoma Lake	Ground Water	Ground Water	City Lake	Hulah Lake	Ground Water	City Lake	Ground Water	Lake Charlott	Ground Water
DATE OF ANALYSIS		6-79	6-79	9-77	6-79	6-79	10-77	9-77	6-79	9-77	9-77	9-77
PARAMETERS	UNIT											
Total Hardness	mg/L	101	78	414	127	119	144	100	184	271	144	162
Total Alkalinity	mg/L	97	26	293	125	78	86	126	133	267	106	164
Chloride	mg/L	12	61	167	12	66	14	< 3	34	62	27	82
Sulfate	mg/L	13	36	25	16	16	47	17	34	91	16	34
Fluoride	mg/L	0.14	0.1	0.27	0.28	0.15	0.40	0 20	0.91	0.25	0.28	0.30
Dissolved Solids	mg/L	133	169	749	175	239	250	213	265	484	218	365
pH	SU	7.4	7.1	7 4	7.2	7.2	7.6	6.9	7.3	7 5	7.6	8.0
Sodium	mg/L	<10	13	70	11	30	25	16	19	81	6.0	68
Nitrite-Nitrate	mg/L	0.3	0.3	0.1	0.1	0.2	0.4	3.5	0 2	0 5	0 1	0.1
Iron	µg/L	<100	< 100	1260	< 100	< 100	< 100	310	<100	< 100	110	<100
Manganese	µg/L	<20	< 20	20.0	< 20	< 20	< 10	10	< 20	10	50	20
Silver	µg/L	< 2	< 2	3	< 2	< 2	< 2	< 2	< 2	2	< 2	< 2
Cadmium	µg/L	4	4	< 1	4	< 2	<1	< 1	4	< 1	4	< 1
Chromium	µg/L	23	27	< 5	26	35	5	< 5	32	< 5	< 5	< 5
Copper	µg/L	< 40	< 40	14	< 40	60	160	33	< 40	8	82	23
Lead	µg/L	14	10	10	16	13	7	< 5	20	10	< 5	< 5
Zinc	µg/L	80	< 40	30	< 40	< 40	140	210	< 40	110	1580	150
Barium	µg/L	<100	< 100	200	< 100	<100	100	100	120	100	< 100	< 100
Arsenic	µg/L	8	6	< 1	4	6	< 1	1	6	< 1	2	2
Selenium	µg/L	4	4	< 1	4	4	< 1	< 1	4	< 1	< 1	< 1
Mercury	µg/L	< 0.5	1 2	< 0.5	1.2	0.8	< 0.5	< 0.5	1 2	< 0.5	< 0.5	< 0 5

(A) Serves Barnsdall RWD.
(B) Serves Greyhorse RWD.

OTTAWA CO.

CITY		Afton	Cardin	Commerce	Fairland	Miami	Peoria RWD 3	Picher	Quapaw	RWD 1	RWD 2	RWD 4	Wyandotte	Wyandotte RWD 1
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		8-78	6-78	6-78	6-78	6-78	6-78	6-78	6-78	5-78	6-78	6-78	6-78	6-78
PARAMETERS	UNIT													
Total Hardness	mg/L	183	127	134	140	139	140	147	146	127	139	132	124	127
Total Alkalinity	mg/L	146	134	134	142	131	145	126	128	137	137	128	131	137
Chloride	mg/L	399	7	10	112	99	4	12	7	12	122	6	3	12
Sulfate	mg/L	15	11	27	13	34	11	29	20	11	11	11	11	11
Fluoride	mg/L	1.4	0.45	0.54	0.71	0.55	0.11	0 24	0.20	0.45	0 75	0.18	0.46	0.45
Dissolved Solids	mg/L	882	166	188	331	324	167	203	191	171	367	163	149	171
pH	SU	7.6	8.3	8.2	8.2	8.2	8.5	8 1	8.4	8.4	8.4	8.3	8 2	8.4
Sodium	mg/L	238	6	9.0	66	63	< 5.0	12	< 5	13	80	< 5.0	7	13
Nitrite-Nitrate	mg/L	0.1	< 0 1	0.1	< 0.1	0.1	< 0.1	< 0.1	< 0 1	< 0.1	0 1	< 0.1	< 0.1	< 0 1
Iron	µg/L	250	1280	1410	920	920	1990	1060	1660	1200	2000	740	1310	1200
Manganese	µg/L	< 20	< 10	10.0	10	< 10	20	< 10	20	< 10	< 10	< 10	20	< 10
Silver	µg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Cadmium	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium	µg/L	13	6	14	68	55	14	43	9	10	50	24	42	10
Copper	µg/L	66	17	3	2	5	24	6	13	3	11	4	8	3
Lead	µg/L	19	6	7	5	8	< 5	7	5	6	< 5	5	6	6
Zinc	µg/L	13	140	10	25	48	66	90	79	43	39	27	56	43
Barium	µg/L	140	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	100	< 100	< 100	< 100
Arsenic	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Selenium	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0 5	< 0.5	< 0.5	< 0.5	< 0.5

ROGERS CO.

CITY		Chelsea	Claremore (A)	RWD 3	RWD 4	RWD 5
SOURCE OF SUPPLY		Chelseahoma Lake	City Lake	Oolagah Res.	Oologah Res.	Verdigris River
DATE OF ANALYSIS		6-79	6-78	6-79	6-79	6-79
PARAMETERS	UNIT					
Total Hardness	mg/L	166	118	106	159	166
Total Alkalinity	mg/L	77	44	69	90	95
Chloride	mg/L	7	13	34	31	31
Sulfate	mg/L	82	67	84	56	60
Fluoride	mg/L	0.22	0.15	0.14	0.18	0.19
Dissolved Solids	mg/L	237	310	275	255	271
pH	SU	7.1	7.3	6.8	7.1	7.2
Sodium	mg/L	< 10	13	21	22	20
Nitrite-Nitrate	mg/L	0.2	0.1	1.3	1.4	0.8
Iron	µg/L	< 100	< 100	< 100	< 100	< 100
Manganese	µg/L	< 20	< 20	< 20	< 20	< 20
Silver	µg/L	< 2	< 2	< 2	< 40	< 2
Cadmium	µg/L	< 2	< 2	< 2	< 2	< 2
Chromium	µg/L	11	10	11	11	10
Copper	µg/L	< 40	< 40	< 40	< 40	< 40
Lead	µg/L	14	10	10	12	15
Zinc	µg/L	< 40	< 40	< 40	< 40	< 40
Barium	µg/L	< 100	< 100	< 100	< 100	< 100
Arsenic	µg/L	< 2	< 2	< 2	< 2	< 2
Selenium	µg/L	< 1	< 1	< 1	< 1	< 1
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

(A) Serves RWD 2, 6, 7, 8 and 9, and Inola

TULSA CO.

CITY		Bixby (A)	Broken Arrow (B)	Collinsville (C)	RWD 2	Sand Springs (D)	Tulsa (E)
SOURCE OF SUPPLY		Bixhoma	Verdigris River	Oologah	Sapulpa	Shell Creek	Spavinaw Eucha Oologah
DATE OF ANALYSIS		7-77	6-79	6-79	11-77	6-79	6-79
PARAMETERS	UNIT						
Total Hardness	mg/L	74	161	169	118	81	84
Total Alkalinity	mg/L	49	75	100	66	46	75
Chloride	mg/L	8	54	43	50	11	9
Sulfate	mg/L	34	77	59	29	27	9
Fluoride	mg/L	0.02	0.17	0.30	0.70	0.60	0.86
Dissolved Solids	mg/L	170	276	257	181	150	127
pH	SU	7.1	6.8	6.9	8.6	7.3	6.9
Sodium	mg/L	6	22	22	15	10	< 10
Nitrite-Nitrate	mg/L	< 0.1	1.1	0.3	0.19	0.1	0.5
Iron	µg/L	< 200	< 100	< 100	160	< 100	< 100
Manganese	µg/L	240	< 20	20	< 10	< 20	< 20
Silver	µg/L	2	< 2	< 2	< 2	< 2	< 2
Cadmium	µg/L	< 1	< 2	2	< 1	2	2
Chromium	µg/L	10	10	< 10	10	10	< 10
Copper	µg/L	2	< 40	< 40	11	< 40	< 40
Lead	µg/L	< 5	15	—	13	< 10	< 10
Zinc	µg/L	66	< 40	< 40	2000	< 40	< 40
Barium	µg/L	< 100	< 100	100	< 100	110	< 100
Arsenic	µg/L	< 1	< 2	< 2	3	< 2	< 2
Selenium	µg/L	< 1	< 1	< 1	< 1	< 1	< 1
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

(A) Serves RWD 8, Wagoner County.
(B) Serves RWD 4 & 5 Wagoner County.
(C) Serves RWD 3 & SAR Water Corp. Washington Co.
(D) Serves RWD 1 & Tulsa Water Improvement Dist. 14.
(E) Serves RWD 3 & 5, Catoosa, Jenks, Owasso, Skiatook, Sperry, Spavinaw, Turley Water Improvement Dist. 1, Jay, West Jay RWD 1, Standby service to Broken Arrow, Bixby, Sapulpa, Sand Springs, Rogers Co. RWD 3, & Wagoner Co RWD 4.

WAGONER CO.

CITY		Coweta (A)	Mallard Bay RWD 1	Okay	Porter (B)	RWD 1	RWD 2	RWD 5 (C)	RWD 7	RWD 8 (D)	Wagoner (E)
SOURCE OF SUPPLY		Verdigris	Ground Water	Verdigris	Ft. Gibson	GRDA	GRDA	Verdigris River	GRDA	Bixby	GRDA
DATE OF ANALYSIS		5-79	8-77	5-79	5-79	5-79	5-79	6-79	5-79	7-77	5-79
PARAMETERS	UNIT										
Total Hardness	mg/L	106	96	80	102	111	116	161	133	74	140
Total Alkalinity	mg/L	54	81	52	54	78	87	75	78	49	84
Chloride	mg/L	37	13	30	31	13	16	54	16	8	15
Sulfate	mg/L	56	31	59	39	55	42	77	35	34	55
Fluoride	mg/L	0.23	0.15	0.13	0.39	0.14	0.15	0.17	0.15	0.02	0.10
Dissolved Solids	mg/L	208	172	195	189	197	191	276	185	170	209
pH	SU	6.7	7.8	6.9	8.2	7	7	68	6.9	7.1	6.9
Sodium	mg/L	15	9	28	10	10	13	22	11	6	< 10
Nitrite-Nitrate	mg/L	1	0.4	0.6	1.2	1.5	1.3	1.1	1.5	0.1	1.6
Iron	µg/L	< 100	< 200	< 100	100	100	100	< 100	120	200	250
Manganese	µg/L	< 20	< 10	30	< 20	< 20	< 20	< 20	< 20	240	40
Silver	µg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	2	< 2
Cadmium	µg/L	3	< 1	4	3	2	1	< 2	2	< 1	3
Chromium	µg/L	14	< 10	12	16	10	10	10	11	10	< 10
Copper	µg/L	< 40	2	< 40	< 40	< 40	< 40	< 40	< 40	2	< 40
Lead	µg/L	10	11	14	19	10	13	15	11	< 5	12
Zinc	µg/L	< 40	20	< 40	< 40	< 40	< 40	< 40	< 40	66	< 40
Barium	µg/L	< 100	< 100	100	< 100	< 100	< 100	< 100	< 100	100	< 100
Arsenic	µg/L	< 2	< 1	< 2	< 2	< 2	< 2	< 2	< 2	< 1	< 2
Selenium	µg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

(A) Serves RWD 5
(B) Served by Muskogee, Muskogee Co
(C) Served by Broken Arrow, Tulsa Co.
(D) Served by Bixby, Tulsa Co.
(E) Serves RWD 6, 9

WASHINGTON CO.

CITY		Bartlesville (A)	Copan	Ochelata	Ramona
SOURCE OF SUPPLY		Hudson Lake	Ground Water	Ochelata Lake	Ground Water
DATE OF ANALYSIS		6-79	7-77	7-77	7-77
PARAMETERS	UNIT				
Total Hardness	mg/L	134	213	129	41
Total Alkalinity	mg/L	77	119	102	87
Chloride	mg/L	30	81	11	8
Sulfate	mg/L	34	55	40	40
Fluoride	mg/L	0.90	0.25	0.09	0.10
Dissolved Solids	mg/L	219	402	252	218
pH	SU	7.3	7.3	6.9	7.7
Sodium	mg/L	18	42	< 5	36
Nitrite-Nitrate	mg/L	0.3	2.6	< 0.1	0.1
Iron	µg/L	< 100	< 200	< 200	< 200
Manganese	µg/L	< 20	< 10	10	590
Silver	µg/L	< 2	4	< 2	< 2
Cadmium	µg/L	< 2	1	2	1
Chromium	µg/L	12	15	10	15
Copper	µg/L	40	275	6	4
Lead	µg/L	10	9	15	< 5
Zinc	µg/L	< 40	23	1700	44
Barium	µg/L	< 100	< 100	< 100	< 100
Arsenic	µg/L	< 2	1	1	< 1
Selenium	µg/L	1	< 1	< 1	< 1
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5

(A) Serves Strike Axe Non-Profit Water Company, and RWD 1 Osage County, RWD 1, 2 & 4, Bar Dew Water District.

NORTH CENTRAL PLANNING REGION

GARFIELD CO.

CITY		Breckinridge	Covington	Douglas	Enid (A)	Fairmont	Garber	Hunter	Kremlin-Hillsdale RWD 1	Lahoma	Waukomis
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		10-78	10-78	10-78	10-78	10-78	10-78	9-77	10-77	10-78	10-78
PARAMETERS	UNIT										
Total Hardness	mg/L	503	241	254	310	472	300	259	257	579	300
Total Alkalinity	mg/L	322	320	305	232	283	281	281	308	448	232
Chloride	mg/L	139	193	44	96	217	168	32	46	338	97
Sulfate	mg/L	100	84	52	32	434	66	36	52	121	32
Fluoride	mg/L	0.23	0 39	0.41	0.74	0.30	0.27	0.40	0.44	0.37	0.79
Dissolved Solids	mg/L	699	767	438	475	1121	683	418	432	1146	468
pH	SU	7.3	7 8	7.4	7.5	7.4	7.4	7.4	7.3	7 3	7.3
Sodium	mg/L	125	225	81	66	240	155	60	80	250	70
Nitrite-Nitrate	mg/L	4.2	4	0.3	6.3	3.6	3.4	0.1	0.3	1 4	6.3
Iron	µg/L	<100	120	<100	<100	100	400	<100	<100	<100	120
Manganese	µg/L	<20	<20	<20	<20	<20	20	380	<20	<20	<20
Silver	µg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Cadmium	µg/L	<1	<1	<1	<1	<1	7	<1	<1	<1	<1
Chromium	µg/L	10	23	<5	<5	6	10	<5	<5	11	7
Copper	µg/L	15	20	125	1800	25	23	95	14	280	15
Lead	µg/L	11	10	19	43	19	31	<5	14	23	10
Zinc	µg/L	460	37	68	21	90	2300	90	52	14	175
Barium	µg/L	<100	150	180	510	<100	<100	<100	160	250	480
Arsenic	µg/L	1	3	<1	<1	7	2	2	<1	4	2
Selenium	µg/L	4	22	<1	3	10.7	4	<1	<1	5	<1
Mercury	µg/L	<0.5	<0 5	<0.5	<0.5	<0.5	0 6	<0 5	<0 5	<0.5	<0 5

(A) Serves Spring Valley Rural Water Association

GRANT CO.

CITY		Deer Creek	Jefferson	Lamont	Manchester (A)	Medford (B)	Nash
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		10-78	1-78	1-78	1-78	9-77	9-77
PARAMETERS	UNIT						
Total Hardness	mg/L	472	301	315	47	341	318
Total Alkalinity	mg/L	370	337	332	63	343	270
Chloride	mg/L	100	96	31	4	31	38
Sulfate	mg/L	118	33	63	14	39	48
Fluoride	mg/L	0.31	0.55	0.41	0 34	0.40	0.60
Dissolved Solids	mg/L	732	446	470	102	444	468
pH	SU	7.5	7.3	7.7	7.0	7.3	7.5
Sodium	mg/L	122	43	47	10	67	42
Nitrite-Nitrate	mg/L	3.5	5.1	0.2	1.2	5.5	8.8
Iron	µg/L	100	100	100	105	<100	120
Manganese	µg/L	<2 0	3 0	65	275	<10	20
Silver	µg/L	2	2	2	<2	<2	2
Cadmium	µg/L	<1	<1	<1	<1	2	<1
Chromium	µg/L	8	<5	<5	<5	<5	<5
Copper	µg/L	20	23	1350	7	110	32
Lead	µg/L	24	8	10	<5	5	10
Zinc	µg/L	100	375	150	725	20	140
Barium	µg/L	150	150	200	50	400	200
Arsenic	µg/L	11	1	<1	<1	1	3
Selenium	µg/L	4	5	<1	<1	2	14
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	3.1	<0.5

(A) Serves RWD 1
(B) Serves R & C Water Corp.

GRANT CO. Continued / KAY CO.

CITY		Pond Creek (C)	Wakita	Blackwell (A)	Braman	Chilocco	Kaw City	Newkirk (B)	O.K. Rural Water	Ponca City (C)	Tonkawa
		GRANT CO. Continued		KAY CO.							
SOURCE OF SUPPLY		Ground Water	Ground Water	Blackwell Lake	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		1-78	9-77	9-77	1-78	8-77	9-77	1-78	9-77	9-77	9-77
PARAMETERS	UNIT										
Total Hardness	mg/L	309	238	155	192	229	170	344	487	236	491
Total Alkalinity	mg/L	409	405	75	120	295	145	248	221	201	304
Chloride	mg/L	118	63	12	72	21	9	173	381	80	51
Sulfate	mg/L	60	78	89	88	32	16	115	135	46	171
Fluoride	mg/L	0.57	0.75	0.28	0.36	0.28	0.19	0.37	0.42	0 70	0.25
Dissolved Solids	mg/L	670	664	245	369	403	281	710	1148	433	768
pH	SU	7.4	7 6	7.9	8.2	7.5	7 2	7.5	7.3	7.3	7.3
Sodium	mg/L	1 20	162	15	53	63	20.0	115	180	56	57
Nitrite-Nitrate	mg/L	0.8	5.9	1.1	0.7	6 1	6.5	1.6	0.9	0.8	1.4
Iron	µg/L	42	<100	<100	46	<100	800	120	1800	110	190
Manganese	µg/L	3.5	10	10.0	4.5	<10	30.0	7 0	11 0	10.0	30.0
Silver	µg/L	3	<2	<2	2	<2	<2	3	6	<2	2
Cadmium	µg/L	<1	1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	µg/L	<5	7	<5	<5	<5	<5	<5	<5	<5	<5
Copper	µg/L	100	76	8	6	38	80	41	200	10	205
Lead	µg/L	8	25	20	<5	<5	25	18	38	<5	5
Zinc	µg/L	85	650	30	75	570	2700	40	11	60	20
Barium	µg/L	150	100	100	50	300	200	150	400	100	<100
Arsenic	µg/L	<1	4	3	1	2	2	<1	<1	2	2
Selenium	µg/L	6	4	<1	2	<1	<1	1	<1	<1	2
Mercury	µg/L	<0.5	2.0	<0.5	<0.5	0.7	<0.5	<0 5	<0 7	<0.5	<0 5

(C) Serves SW Water Inc.

(A) Serves Blackwell Rural Water Corp
(B) Serves Dale Water Corp.
(C) Serves RWD 1, 2, & 3.

KINGFISHER CO.

CITY		Cashion	Dover (A)	Hennessey	Kingfisher (B)	Okarche
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		1-78	9-77	9-77	9-77	9-77
PARAMETERS	UNIT					
Total Hardness	mg/L	331	559	353	339	296
Total Alkalinity	mg/L	319	253	248	270	248
Chloride	mg/L	126	115	188	83	77
Sulfate	mg/L	46	83	51	65	50
Fluoride	mg/L	0.20	0.60	0.40	0.45	0 35
Dissolved Solids	mg/L	621	819	742	538	508
pH	SU	7.4	7.3	7.1	7.4	7.2
Sodium	mg/L	95	85	115	60	65
Nitrite-Nitrate	mg/L	6.8	16.2	6.8	2.9	26 1
Iron	µg/L	120	<100	<100	<100	<100
Manganese	µg/L	<20	30	30	40	40
Silver	µg/L	2	<2	<2	3	<2
Cadmium	µg/L	<1	2	<1	<1	3
Chromium	µg/L	<5	5	<5	6	10
Copper	µg/L	20	22	27	128	36
Lead	µg/L	20	<5	<5	<5	<5
Zinc	µg/L	27	40	40	20	600
Barium	µg/L	250	100	200	200	100
Arsenic	µg/L	2	<1	<1	1	<1
Selenium	µg/L	1	4	3	3	16
Mercury	µg/L	<0.5	<0 5	<0.5	<0 5	<0.5

(A) Serves RWD 3.
(B) Serves RWD 2.

LINCOLN CO.

CITY		Big Creek (A)	Carney	Chandler	Davenport	Meeker	Prague	Sparks RWD 1	Stroud	Wellston
SOURCE OF SUPPLY		Ground Water	Ground Water	Lake Chandler	Lake Davenport	Ground Water	Ground Water	Sparks Lake	Lake Stroud	Ground Water
DATE OF ANALYSIS		6-76	6-77	5-77	5-77	5-77	6-77	7-79	5-77	6-77
PARAMETERS	UNIT									
Total Hardness	mg/L	252	219	143	143	166	166	74	122	45
Total Alkalinity	mg/L	242	273	130	192	169	163	71	112	446
Chloride	mg/L	17	11	16	57	10	5	8	10	187
Sulfate	mg/L	23	10	64	24	·20	178	14	33	184
Fluoride	mg/L	—	0.39	0.30	0.30	0.20	0.69	0.15	0.20	2.1
Dissolved Solids	mg/L	301	—	—	—	—	—	119	—	—
pH	SU	7.4	8.0	7.7	7.6	7.5	7.9	7.3	7.6	9
Sodium	mg/L	—	65	—	—	—	102	10	—	540
Nitrite-Nitrate	mg/L	—	0.2	0.1	0.1	0.2	0.2	< 5	0.1	< 0.1
Iron	µg/L	0.8	< 200	< 200	< 200	< 200	< 200	< 100	< 200	< 200
Manganese	µg/L	141	< 10	20.0	10.0	< 10.0	20.0	20	< 10	< 10
Silver	µg/L	—	< 1	< 1	< 1	3	< 1	< 2	1	5
Cadmium	µg/L	111	2	1	< 1	< 1	3	2	< 1	2
Chromium	µg/L	—	10	2	2	2	15	< 10	5	12
Copper	µg/L	—	—	—	—	—	—	< 40	—	—
Lead	µg/L	—	2	8	< 1	5	11	13	6	13
Zinc	µg/L	—	—	—	—	—	—	< 40	—	—
Barium	µg/L	—	600	100	100	100	400	< 100	100	700
Arsenic	µg/L	—	2	< 1	2	< 1	2	< 5	1	12
Selenium	µg/L	—	4	< 1	< 1	1	2	< 5	2	< 1
Mercury	µg/L	—	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

(A) Serves Agra.

LOGAN CO.

CITY		Coyle	Crescent	Guthrie	Langston	Marshall	Mulhall	Orlando
SOURCE OF SUPPLY		Ground Water	Ground Water	Guthrie Lake	Langston Lake	Otter Creek	Ground Water	Ground Water
DATE OF ANALYSIS		1-79	1-79	1-79	1-79	5-77	9-77	1-79
PARAMETERS	UNIT							
Total Hardness	mg/L	619	165	257	151	535	484	368
Total Alkalinity	mg/L	437	187	233	123	285	341	390
Chloride	mg/L	299	32	32	18	330	54	33
Sulfate	mg/L	293	28	29	136	20	80	60
Fluoride	mg/L	0.35	0.19	0.62	0.15	0.30	0.25	0.57
Dissolved Solids	mg/L	1241	307	316	205	—	591	477
pH	SU	7.2	7.1	7.8	7.7	8.0	7.2	7.4
Sodium	mg/L	219	46	37	20	—	40	69
Nitrite-Nitrate	mg/L	6.3	5.3	0.2	0.1	0.1	9.6	0.1
Iron	µg/L	< 300	< 300	< 300	300	200	< 100	320
Manganese	µg/L	180	< 20	< 20	40	30.0	70.0	240
Silver	µg/L	3	< 2	< 2	< 2	5	< 2	< 2
Cadmium	µg/L	< 1	< 1	< 1	< 1	3	3	< 1
Chromium	µg/L	7	< 5	9	8	7	15	< 5
Copper	µg/L	11	12	12	68	—	75	28
Lead	µg/L	20	9	12	7	18	6	11
Zinc	µg/L	18	75	15	7	—	50	70
Barium	µg/L	214	214	286	15	600	200	214
Arsenic	µg/L	< 1	1	2	1	< 1	1	< 1
Selenium	µg/L	1	2	< 1	< 1	1	1	< 1
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1.0	< 0.5

LOGAN CO. Continued

CITY		RWD 1	RWD 2
SOURCE OF SUPPLY		Ground Water	Ground Water
DATE OF ANALYSIS		1-79	1-79
PARAMETERS	UNIT		
Total Hardness	mg/L	299	78
Total Alkalinity	mg/L	296	108
Chloride	mg/L	30	35
Sulfate	mg/L	< 3	21
Fluoride	mg/L	0.29	0.24
Dissolved Solids	mg/L	293	209
pH	SU	7.5	7.1
Sodium	mg/L	22	35
Nitrite-Nitrate	mg/L	< 0.1	6
Iron	µg/L	< 300	< 300
Manganese	µg/L	< 20	< 20
Silver	µg/L	< 2	< 2
Cadmium	µg/L	< 1	< 1
Chromium	µg/L	< 5	< 5
Copper	µg/L	270	160
Lead	µg/L	15	5
Zinc	µg/L	150	28
Barium	µg/L	571	143
Arsenic	µg/L	2	1
Selenium	µg/L	4	< 1
Mercury	µg/L	< 0.5	< 0.5

NOBLE CO.

CITY		Billings	Bressie	Lucien RWD 1	Marland (A)	Morrison (B)	Perry	Red Rock
SOURCE OF SUPPLY		Ground Water	Ground Water	Lake Carl Blakely	Ground Water	Private Lake	Lake Perry	Ground Water
DATE OF ANALYSIS		7-77	8-79	8-79	7-77	5-77	5-77	7-77
PARAMETERS	UNIT							
Total Hardness	mg/L	731	371	87	246	150	145	623
Total Alkalinity	mg/L	406	257	17	377	102	105	465
Chloride	mg/L	577	364	11	92	36	34	120
Sulfate	mg/L	205	122	54	78	63	65	107
Fluoride	mg/L	0.32	0.16	0.09	0.45	0.30	0.2	0.31
Dissolved Solids	mg/L	1765	1046	145	524	—	—	902
pH	SU	7.1	7.4	8.8	7.2	7.4	7.5	7.4
Sodium	mg/L	280	221	10	50	—	—	—
Nitrite-Nitrate	mg/L	< 0.1	0.4	1.0	1.7	0.1	< 0.1	0.5
Iron	µg/L	1540	< 100	< 100	< 200	< 200	< 200	< 200
Manganese	µg/L	100	< 20	< 20	< 10	< 10	< 10	20
Silver	µg/L	5	< 2	< 2	3	3	1	4
Cadmium	µg/L	1	6	3	1	1	1	1
Chromium	µg/L	40	12	13	20	5	3	30
Copper	µg/L	8	< 40	< 40	9	—	—	74
Lead	µg/L	18	30	17	13	6	6	18
Zinc	µg/L	95	170	< 40	95	—	—	110
Barium	µg/L	200	130	< 100	400	300	300	200
Arsenic	µg/L	< 1	< 5	< 0.5	2	25	1	3
Selenium	µg/L	< 1	< 5	< 5	2	< 1	< 1	2
Mercury	µg/L	< 0.5	< 0.5	< 0.5	1.0	1.0	0.8	< 0.5

(A) Serves Marland Water Inc.
(B) Serves Morr Water Corp.

PAWNEE CO.

CITY		Blackburn-Skedee	Cleveland (A)	Hallett	Jennings	Pawnee (B)	Ralston (C)
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Pawnee Lake	Ground Water
DATE OF ANALYSIS		6-78	5-77	11-77	5-78	5-77	11-77
PARAMETERS	UNIT						
Total Hardness	mg/L	574	113	220	54	160	370
Total Alkalinity	mg/L	421	100	270	257	154	349
Chloride	mg/L	41	19	31	105	13	44
Sulfate	mg/L	37	28	38	107	268	38
Fluoride	mg/L	0.35	0.20	0.36	0.65	0.30	0.28
Dissolved Solids	mg/L	683	—	425	549	—	528
pH	SU	7.0	7.3	7.5	8.1	7.7	7.3
Sodium	mg/L	27	—	70	178	—	—
Nitrite-Nitrate	mg/L	< 0.1	0.1	0.9	< 0.1	0.1	3.1
Iron	µg/L	660	350	2750	230	< 200	135
Manganese	µg/L	300	340	47	30	20	17
Silver	µg/L	< 2	3	< 2	< 2	1	3
Cadmium	µg/L	< 1	< 1	< 1	< 1	1	< 1
Chromium	µg/L	< 5	7	10	< 5	6	7
Copper	µg/L	41	—	3	5	—	14
Lead	µg/L	33	15	< 5	< 5	5	12
Zinc	µg/L	265	—	190	31	—	60
Barium	µg/L	330	100	< 100	< 100	< 100	800
Arsenic	µg/L	< 1	< 1	< 1	< 1	< 1	< 1
Selenium	µg/L	< 1	< 1	< 1	< 1	< 1	2.2
Mercury	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

(A) Serves RWD 1
(B) Serves RWD 3.
(C) Serves Ralston Water Inc

		PAWNEE CO. Continued		PAYNE CO.						
CITY		RWD 2 (D)	RWD 2 Inc. (E)	Cushing	Glencoe	Perkins	Ripley	RWD 3	Stillwater (A)	Yale (B)
SOURCE OF SUPPLY		Ground Water	Mannford City Lake	Lake Cushing	Ground Water	Ground Water	Ground Water	Ground Water	Lake Carl Blackwell	Ground Water
DATE OF ANALYSIS		10-77	6-78	5-77	6-78	6-78	6-78	6-78	5-77	5-78
PARAMETERS	UNIT									
Total Hardness	mg/L	282	103	171	409	198	476	153	207	363
Total Alkalinity	mg/L	202	62	159	233	144	305	161	730	283
Chloride	mg/L	91	58	45	20	40	39	12	58	134
Sulfate	mg/L	50	46	20	203	31	71	24	36	48
Fluoride	mg/L	0.34	0.70	0.30	0.49	0.26	0.47	0.40	0.90	0.35
Dissolved Solids	mg/L	464	231	—	591	328	587	223	—	608
pH	SU	7.2	7.5	7.7	7.6	—	7.4	6.9	7.9	7.3
Sodium	mg/L	35	21	—	39	37	34	22	—	71
Nitrite-Nitrate	mg/L	0.1	<0.1	0.1	1.5	7.4	0.3	5.0	<0.1	2.1
Iron	µg/L	<100	160	<200	<100	130	<100	<100	<200	140
Manganese	µg/L	<10	<20	<10	<20	<20	240	<20	<10	<20
Silver	µg/L	2	<2	2	<2	<2	<2	<2	3	3
Cadmium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	1
Chromium	µg/L	8	<5	3	<5	<5	<5	<5	6	<5
Copper	µg/L	63	20	—	80	27	25	170	—	35
Lead	µg/L	9	8	8	17	20	25	8	5	17
Zinc	µg/L	31	23	—	100	100	100	45	—	58
Barium	µg/L	100	<100	300	<100	520	310	170	<100	620
Arsenic	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.8	<0.5

(D) Serves Terlton.
(E) Purchases water from Mannford, Creek County.

(A) Serves RWD 1, Fifty-One East Water Inc. and Payne Co. Rural Water Corp. 3.
(B) Serves Yale Rural Water Corp.

NORTHWEST PLANNING REGION

ALFALFA CO.

CITY		Aline	Carmen	Cherokee	Goltry	Helena	Jet	RWS & SWMD 1	RWS & SWMD 1 (A) North
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		1-78	1-78	1-78	2-78	1-78	1-78	4-79	10-78
PARAMETERS	UNIT								
Total Hardness	mg/L	499	350	735	215	282	219	180	631
Total Alkalinity	mg/L	238	310	434	241	334	337	172	314
Chloride	mg/L	98	55	92	42	63	79	10	119
Sulfate	mg/L	144	95	376	24	32	37	16	174
Fluoride	mg/L	0.46	0.46	0.40	0.51	0.37	0.81	0.31	0.48
Dissolved Solids	mg/L	796	533	1162	397	493	579	310	727
pH	SU	7.4	7.5	7.4	7.3	7.4	7.7	7.8	7.3
Sodium	mg/L	55.0	65.0	150.0	75.0	85.0	154	30	70
Nitrite-Nitrate	mg/L	16.2	6.1	7.4	7.4	4.0	13.7	—	16.2
Iron	µg/L	180	<40	130	300	<40	<40	140	190
Manganese	µg/L	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20	20
Silver	µg/L	4	3	3	<2	<2	3	<2	3
Cadmium	µg/L	<1	<1	<1	1	<1	<1	<2	<2
Chromium	µg/L	<5	5	12	8	22	7	9	6
Copper	µg/L	13	850	34	38	75	16	10	28
Lead	µg/L	28	88	98	40	41	15	11	27
Zinc	µg/L	1050	90	70	255	27	75	17	35
Barium	µg/L	<50	<50	<50	150	100	100	200	100
Arsenic	µg/L	<1	1	1	1	<1	1	<2	2
Selenium	µg/L	4	6	8	<1	3	6	<1	3
Mercury	µg/L	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7

(A) Serves Lambert, Amorita, Byron, Burlington, Driftwood and Yewed

BEAVER CO.

CITY		Beaver	Beaver State Park	Forgan	Gate RWD 2	Knowles	Turpin RWD 1
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		1-78	1-78	1-78	1-79	1-78	12-78
PARAMETERS	UNIT						
Total Hardness	mg/L	246	234	268	250	228	200
Total Alkalinity	mg/L	214	211	223	232	186	210
Chloride	mg/L	34	17	58	30	27	36
Sulfate	mg/L	35	18	45	35	18	59
Fluoride	mg/L	0.55	0.60	0.43	0.39	0.51	1.7
Dissolved Solids	mg/L	351	285	437	361	291	401
pH	SU	7.6	7.6	7.6	7.1	7.5	7.6
Sodium	mg/L	27	19	47	17	18	45
Nitrite-Nitrate	mg/L	3.0	0.7	47	3.7	2.3	3.3
Iron	µg/L	8.0	1015	31	150	105	58
Manganese	µg/L	3.0	27.0	2	7	5.0	3
Silver	µg/L	<2	<2	3	<2	<2	<2
Cadmium	µg/L	<1	8	<1	2	<1	2
Chromium	µg/L	<5	<5	<5	5	<5	10
Copper	µg/L	23	15	19	105	12	7
Lead	µg/L	6	34	8	16	6	8
Zinc	µg/L	180	1400	22	50	425	195
Barium	µg/L	<50	550	400	214	100	<100
Arsenic	µg/L	1	<1	<1	2	<1	3
Selenium	µg/L	5	2	8	2	—	5
Mercury	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.5

BLAINE CO.

BLAINE CITY		Canton	Geary	Greenfield	Hitchcock	Longdale	North Blaine Water (A)	Watonga
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Springs	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		9-77	9-77	9-77	9-77	8-77	1-78	9-77
PARAMETERS	UNIT							
Total Hardness	mg/L	214	230	721	217	222	263	233
Total Alkalinity	mg/L	244	185	449	180	186	196	211
Chloride	mg/L	12	37	71	32	18	57	11
Sulfate	mg/L	21	21	629	58	56	63	41
Fluoride	mg/L	0.30	0.30	0.30	0.30	0.40	0.37	0.40
Dissolved Solids	mg/L	376	40.2	1544	4.42	3.69	428	325
pH	SU	8.2	7.1	7.1	7.1	7.3	7.2	7.3
Sodium	mg/L	39.0	45.0	176.0	49.0	19.0	50.0	25.0
Nitrite-Nitrate	mg/L	2.3	12.7	1.9	10.8	2.8	9.5	3.4
Iron	µg/L	<100	<100	<100	110	<100	50	<100
Manganese	µg/L	<10.0	100	30.0	<10.0	<10.0	<20	<10.0
Silver	µg/L	2	2	6	3	2	2	2
Cadmium	µg/L	<1	1	<1	2	<1	<1	<1
Chromium	µg/L	<10	10	10	<10	<10	5	10
Copper	µg/L	14	90	28	110	3	35	52
Lead	µg/L	10	10	18	5	10	53	7
Zinc	µg/L	60	220	40	70	70	150	20
Barium	µg/L	100	300	100	<100	200	100	<100
Arsenic	µg/L	5	2	2	<1	<1	<1	2
Selenium	µg/L	<1	1	6	1	1	3	1
Mercury	µg/L	<0.5	<0.5	<5	<0.5	<0	<0.5	0.8

(A) Serves Okeene, Okarche RWD & Loyal

CIMARRON CO.

CITY	Boise City	Felt	Keyes
SOURCE OF SUPPLY	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS	1-78	1-78	1-78
Total Hardness	226	177	208
Total Alkalinity	171	177	168
Chloride	22	5	13
Sulfate	43	26	43
Fluoride	1.21	1.30	2.3
Dissolved Solids	317	243	283
pH	7.8	7.8	8
Sodium	23.0	24	19
Nitrite-Nitrate	2.7	1.5	1.3
Iron	30	64	79
Manganese	3.5	2	1.5
Silver	3	<2	<2
Cadmium	<1	<1	<1
Chromium	<5	<5	<5
Copper	295	8	105
Lead	9	<5	5
Zinc	750	490	220
Barium	50	<50	<50
Arsenic	<1	<1	2
Selenium	5	2	<1
Mercury	<0.5	0.8	<0.5

DEWEY

DEWEY CO.

CITY	UNIT	Camargo RWD 2	Leedey	Mutual & Lenora RWD 3	Oakwood RWD 1	Seiling	Taloga	Vici
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		1-78	10-77	N/A	10-78	1-78	1-78	1-78
PARAMETERS	UNIT							
Total Hardness	mg/L	191	221	—	270	271	479	215
Total Alkalinity	mg/L	173	233	—	210	207	272	205
Chloride	mg/L	1	4	—	40	12	27	4
Sulfate	mg/L	16	13	—	19	73	186	16
Fluoride	mg/L	0.16	0.24	—	0.14	0.65	0.41	0.37
Dissolved Solids	mg/L	244	316	—	348	407	672	299
pH	SU	7.70	7.50	—	7 6	7.6	7 4	7.6
Sodium	mg/L	<1	25	—	25	20.0	40.0	25.0
Nitrite-Nitrate	mg/L	3.3	5 7	—	5 3	6.4	14.1	7.1
Iron	µg/L	110	<100	—	120	70	60	70
Manganese	µg/L	<20.0	<10.0	—	<20	<20.0	< 20.0	<20.0
Silver	µg/L	2	<2	—	< 2	2	3	2
Cadmium	µg/L	3	<1	—	<1	<1	<1	1
Chromium	µg/L	<5	<5	—	8	<5	<5	<5
Copper	µg/L	15	6	—	6	23	6	11
Lead	µg/L	25	20	—	14	28	25	19
Zinc	µg/L	1060	85	—	165	23	12	41
Barium	µg/L	856	400	—	357	50	50	450
Arsenic	µg/L	<1	2	—	3	1	<1	<1
Selenium	µg/L	<1	<1	—	<1	7	3	<1
Mercury	µg/L	<0.5	<0.5	—	0.6	<0 5	< 0 5	<0.5

ELLIS CO.

CITY	UNIT	Arnett	Fargo	Gage	Shattuck
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		2-78	2-78	2-78	3-78
PARAMETERS	UNIT				
Total Hardness	mg/L	61	248	246	204
Total Alkalinity	mg/L	181	197	251	184
Chloride	mg/L	13	43	45	22
Sulfate	mg/L	6	83	53	9
Fluoride	mg/L	0.19	0.40	0.45	0.43
Dissolved Solids	mg/L	338	972	506	358
pH	SU	7 7	7.6	7.5	7 5
Sodium	mg/L	<20.0	30.0	35.0	14
Nitrite-Nitrate	mg/L	1.8	7.1	8 8	1.4
Iron	µg/L	40	100	80	<50
Manganese	µg/L	<20.0	<20.0	<20 0	<10
Silver	µg/L	<2	2	2	<2
Cadmium	µg/L	<1	<1	<1	<1
Chromium	µg/L	<5	<5	<5	18
Copper	µg/L	1600	4	13	12
Lead	µg/L	13	54	52	10
Zinc	µg/L	210	22	13	63
Barium	µg/L	200	<100	260	350
Arsenic	µg/L	3	6	3	2
Selenium	µg/L	3	1	<1	<1
Mercury	µg/L	<0 5	<0.5	<0.5	<0 5

HARPER CO.

CITY	UNIT	Buffalo (A)	Laverne	Selman
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		2-78	2-78	2-78
PARAMETERS	UNIT			
Total Hardness	mg/L	209	244	263
Total Alkalinity	mg/L	261	297	243
Chloride	mg/L	30	128	21
Sulfate	mg/L	47	121	75
Fluoride	mg/L	0 40	0 73	0.36
Dissolved Solids	mg/L	436	766	426
pH	SU	7.6	7.5	7 7
Sodium	mg/L	50 0	90.0	<20.0
Nitrite-Nitrate	mg/L	3.7	5.4	3.1
Iron	µg/L	160	<40	40
Manganese	µg/L	<20.0	<20.0	<20.0
Silver	µg/L	3	3	2
Cadmium	µg/L	<1	< 1	<1
Chromium	µg/L	9	< 5	<5
Copper	µg/L	25	9	18
Lead	µg/L	52	15	20
Zinc	µg/L	280	60	57
Barium	µg/L	120	<100	300
Arsenic	µg/L	6	4	7
Selenium	µg/L	3	3	1
Mercury	µg/L	<0.5	<0.5	<0.5

(A) Serves Harper Co. Water Corp.

MAJOR CO.

CITY	UNIT	Ames	Cleo Springs	Fairview	Meno	Ringwood	RWS & SWD 1
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		10-78	10-78	2-79	10-78	12-78	9-77
PARAMETERS	UNIT						
Total Hardness	mg/L	335	227	268	399	286	232
Total Alkalinity	mg/L	210	210	238	258	281	130
Chloride	mg/L	387	53	50	151	37	45
Sulfate	mg/L	170	17	40	28	14	69
Fluoride	mg/L	0 34	0.23	0.29	0.42	0.36	0.30
Dissolved Solids	mg/L	1313	426	412	576	372	414
pH	SU	7.7	7.8	7.5	7.7	7.9	6.8
Sodium	mg/L	314	30	52	70	40	20
Nitrite-Nitrate	mg/L	1 3	8 4	5 5	4.3	3	2.9
Iron	µg/L	180	<100	320	<100	170	100
Manganese	µg/L	<20	<20	30	<20	<20	20.0
Silver	µg/L	<2	<2	<2	<2	<2	<2
Cadmium	µg/L	<2	<2	<2	<2	<2	1
Chromium	µg/L	40	7	9	12	7	5
Copper	µg/L	6	100	43	17	580	34
Lead	µg/L	12	18	12	10	21	<5
Zinc	µg/L	110	645	83	195	300	100
Barium	µg/L	110	420	530	450	420	<100
Arsenic	µg/L	9	62	<2	<2	<2	<1
Selenium	µg/L	4	<1	<1	7	1	4
Mercury	µg/L	<0 5	<0.5	<0.5	<0 5	<0.5	<0 5

TEXAS CO.

CITY	UNIT	Adams RWD 1	Goodwell	Guymon	Hardesty RWD 2	Hooker	Optima	Panhandle St Univ	Texhoma	Tyrone
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		12-78	12-78	12-78	12-78	1-78	12-79	12-78	12-78	1-78
PARAMETERS	UNIT									
Total Hardness	mg/L	259	220	311	243	289	311	220	263	223
Total Alkalinity	mg/L	212	196	228	190	165	205	196	217	194
Chloride	mg/L	14	12	14	20	14	11	13	17	15
Sulfate	mg/L	47	44	99	82	127	124	40	49	53
Fluoride	mg/L	1 6	1 89	2	1.77	0.91	0.89	1.89	1 57	0 66
Dissolved Solids	mg/L	332	332	429	373	440	446	330	359	370
pH	SU	7.6	7.6	7.7	7.4	7 6	7.5	7 6	7.6	7.8
Sodium	mg/L	15	23	31	30	25	29	24	24	29
Nitrite-Nitrate	mg/L	3.1	3 4	2 6	2	3.5	2 2	3 4	3.3	3.4
Iron	µg/L	78	64	61	215	105	130	89	73	105
Manganese	µg/L	2	2	2	4	3.5	4	2	2	4.5
Silver	µg/L	<2	<2	<2	<2	3	<2	<2	<2	2
Cadmium	µg/L	1	1	1	2	<1	1	2	1	1
Chromium	µg/L	7	9	10	6	<5	6	7	6	<5
Copper	µg/L	13	20	8	260	33	22	5	8	22
Lead	µg/L	<2	<2	9	9	7	<2	<2	9	7
Zinc	µg/L	120	19	80	500	100	270	395	95	135
Barium	µg/L	<100	<100	<100	<100	100	<100	<100	<100	50
Arsenic	µg/L	3	4	3	3	<1	<1	5	3	<1
Selenium	µg/L	2	2	2	1	4	2	2	2	7
Mercury	µg/L	<0.5	<0.5	<0 5	<0 5	<0 5	<0 5	<0.5	<0.5	<0 5

WOODS CO.

CITY		Alva (A)	Avaro	Freedom (B)	Lookout	RWD 2 (C)	Waynoka RWD 3
SOURCE OF SUPPLY		Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water
DATE OF ANALYSIS		10-78	10-78	10-78	10-78	9-77	10-78
PARAMETERS	UNIT						
Total Hardness	mg/L	193	226	214	182	163	138
Total Alkalinity	mg/L	166	244	158	175	150	115
Chloride	mg/L	18	7	<1	7	19	47
Sulfate	mg/L	25	65	16	16	15	53
Fluoride	mg/L	0.24	0.28	0 26	0.27	0.25	0.32
Dissolved Solids	mg/L	299	349	239	332	229	379
pH	SU	7.1	7.7	7.2	7.6	7.2	7.5
Sodium	mg/L	20	20	27	13	15	30
Nitrite-Nitrate	mg/L	4.8	4 5	6.8	5.5	5.1	5.1
Iron	µg/L	140	<100	290	280	<100	480
Manganese	µg/L	<20	<20	<20	<20	10	20
Silver	µg/L	<2	<2	2	<2	<2	2
Cadmium	µg/L	<2	2	<2	<2	1	<1
Chromium	µg/L	7	<5	<5	6	<5	6
Copper	µg/L	270	6	9	56	13	18
Lead	µg/L	12	20	<5	14	5	11
Zinc	µg/L	62	67	11	210	460	250
Barium	µg/L	230	<100	220	430	100	200
Arsenic	µg/L	<2	<2	<2	<2	<1	<2
Selenium	µg/L	<1	<1	<1	<1	1	<1
Mercury	µg/L	1.2	<0 5	<0.5	<0.5	<0.5	<0 5

(A) Serves Capron RWD 1, RWD 3 & Hopetown.
(B) Purchases from RWD 1, Woodward County.
(C) Purchases from the state of Kansas

WOODWARD CO.

CITY		Ft. Supply	Mooreland	Quinlan	RWD 1 (A)	RWD 2	Sharon	Western State Hospital	Woodward
SOURCE OF SUPPLY		Ft. Supply Lake	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ft. Supply Lake	Ground Water
DATE OF ANALYSIS		9-77	10-78	10-78	10-78	10-78	10-78	10-78	10-78
PARAMETERS	UNIT								
Total Hardness	mg/L	—	347	135	214	275	218	149	208
Total Alkalinity	mg/L	421	273	62	158	188	192	24	186
Chloride	mg/L	201	53	<1	<1	<1	5	124	9
Sulfate	mg/L	187	62	7	16	18	6	114	23
Fluoride	mg/L	0.80	0.27	0.31	0 26	0.37	0.33	0.48	0 23
Dissolved Solids	mg/L	1140	494	174	239	315	268	490	230
pH	SU	7.7	7.4	7.1	7.2	7.5	7.5	9.3	7.6
Sodium	mg/L	175	48	<10	27	12	12	130	23
Nitrite-Nitrate	mg/L	1.9	8.8	7.3	6.8	5.8	4.7	0.1	1.6
Iron	µg/L	350	120	230	290	330	<100	250	100
Manganese	µg/L	60	<20	<20	<20	<20	<20	<20	20
Silver	µg/L	<2	<2	<2	2	<2	<2	<2	<2
Cadmium	µg/L	3	<1	<2	<2	<2	<1	<2	<1
Chromium	µg/L	5	<5	<5	<5	<5	<5	<5	7
Copper	µg/L	4	480	9	9	37	20	<5	150
Lead	µg/L	11	39	<5	<5	15	15	5	12
Zinc	µg/L	530	190	825	11	21	1500	140	66
Barium	µg/L	<100	270	150	220	700	800	<100	170
Arsenic	µg/L	<1	<1	<2	<2	<2	<1	<2	<1
Selenium	µg/L	<1	2	1	<1	<1	<1	<1	<1
Mercury	µg/L	<0.5	<0 5	<0.5	<0.5	<0.5	<0.5	<0 5	<0 5

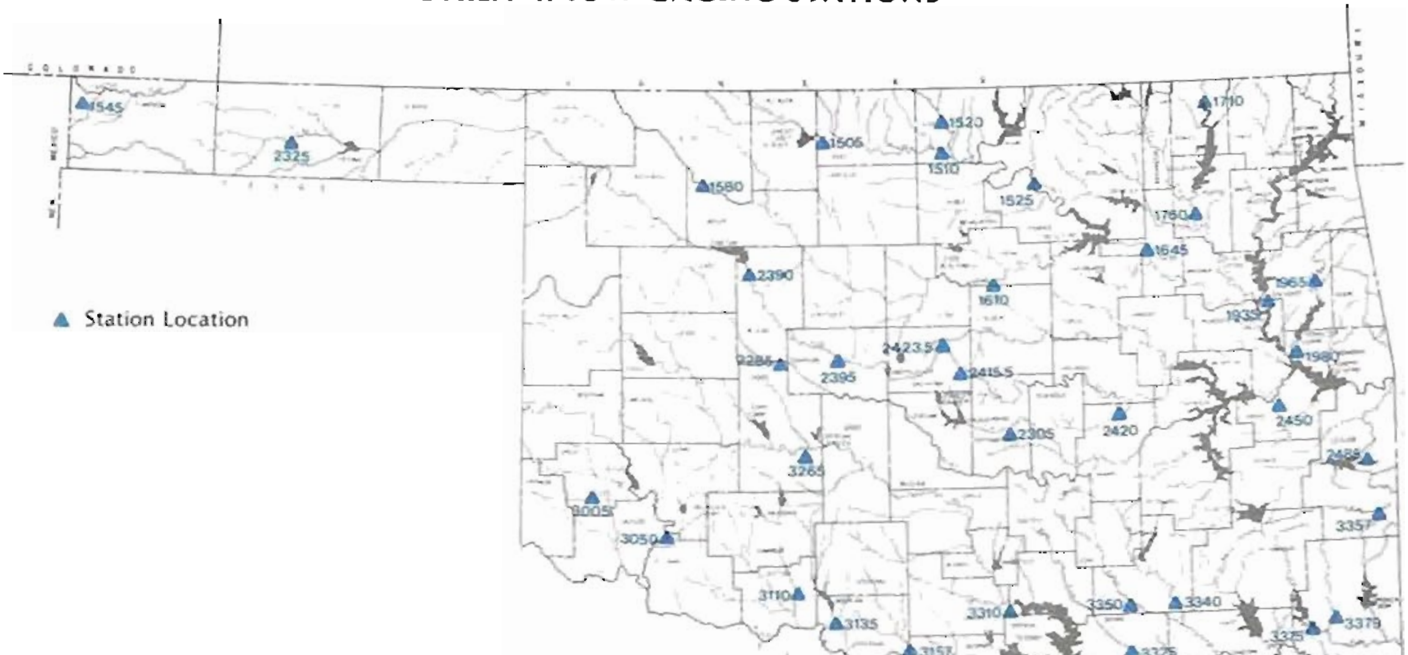
(A) Serves Freedom, Woods County.

APPENDIX B

FIGURE 2 STREAMFLOW SUMMARY FOR SELECTED USGS GAGING STATIONS

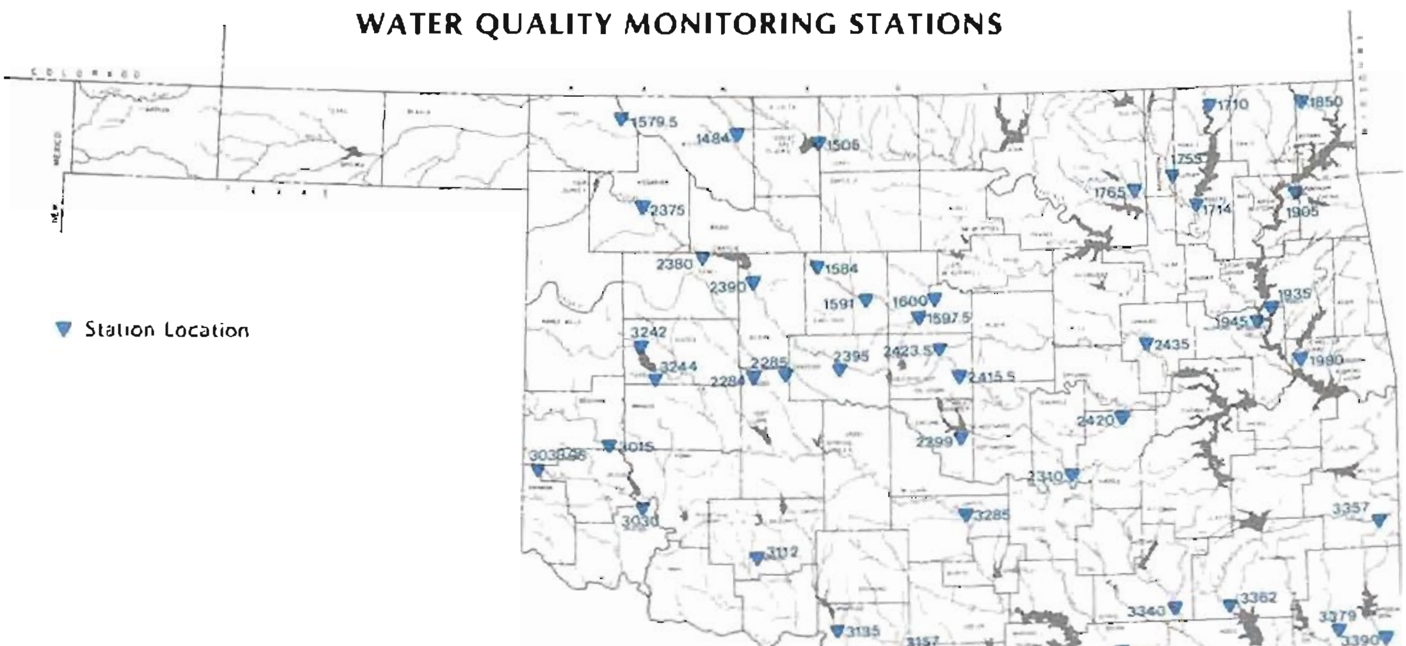
PLANNING REGION	STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA (SQ. MI.)	AVERAGE ANNUAL FLOW (AF/YR)	OBSERVED FLOW (cfs) MAX.	MIN.	PERIOD OF RECORD
Southeast	Red River at Denison Dam near Denison, Tx	3316	33,784	3,181,000	201,000	12	1923
	Blue River near Blue	3325	476	218,800	34,400	0	1936
	Muddy Boggy Creek near Farris	3340	1,087	657,800	61,900	0	1937
	Clear Boggy Creek near Caney	3350	720	358,600	52,800	0	1942
	Little River near Wright City	3375	645	743,300	78,200	0	1929-31, 44
	Glover Creek near Glover	3379	315	330,400	98,600	0	1961
Central	Little River near Tecumseh	2305	456	56,870	32,400	0	1943
	North Canadian River near El Reno	2395	8,143	144,200	15,000	0	1902-08, 37
	North Canadian River near Harrah	2415.5	8,602	205,000	6,920	23	1968
	Deep Fork near Arcadia	2423.5	105	46,080	14,300	14	1969
South Central	Beaver Creek near Waurika	3135	563	77,520	32,200	0	1953
	Mud Creek near Courtney	3157	572	83,320	33,400	0	1960
	Red River near Gainesville, Tx.	3160	24,846	1,992,000	168,000	48	1936
	Washita River near Durwood	3310	7,202	1,010,000	98,000	0	1928
	Red River at Denison Dam, near Denison, Tx.	3316	33,784	3,181,000	201,000	12	1923
Southwest	Salt Fork Red River at Mangum	3005	1,357	63,760	72,000	0	1905-06, 37
	North Fork Red River near Headrick	3050	3,845	198,500	35,000	0	1905-08, 37
	East Cache Creek near Walters	3110	675	121,000	28,200	0	1938-63, 69
	Washita River at Anadarko	3265	3,656	278,900	29,000	0	1902-08, 24-25, 35-38, 63
East Central	North Canadian River near Wetumka	2420	9,391	486,900	66,000	0	1937
	Canadian River near Whitefield	2450	37,876	4,185,000	281,000	0.4	1938
	Poteau River near Wister	2485	993	763,600	79,600	0	1938
	Kiamichi River near Big Cedar	3357	40	55,790	21,500	0	1965
Northeast	Arkansas River at Ralston	1525	46,850	3,496,000	211,000	14	1925
	Arkansas River at Tulsa	1645	62,074	5,175,000	246,000	27	1925
	Verdigris River near Lenapah	1710	3,639	1,964,000	137,000	0	1938
	Verdigris River near Claremore	1760	6,534	2,983,000	182,000	0	1935
	Neosho River below Ft. Gibson Lk, near Ft. Gibson	1935	12,495	5,644,000	223,000	12	1950
	Illinois River near Tahlequah	1965	959	652,800	150,000	0.1	1935
	Illinois River near Gore	1980	1,626	1,122,000	180,000	2	1924-26, 39
North Central	Salt Fork Arkansas River at Tonkawa	1510	4,520	534,700	97,300	0	1903-05, 35
	Chikaskia River near Blackwell	1520	1,859	350,700	85,000	0	1935
	Arkansas River at Ralston	1525	46,850	3,496,000	211,000	14	1925
	Cimarron River at Perkins	1610	12,926	856,400	149,000	0.8	1939
Northwest	Salt Fork Arkansas River near Jet	1505	3,194	268,800	25,900	0	1937
	Cimarron River near Kenton	1545	1,038	16,950	43,400	0	1904-05, 1950
	Cimarron River near Waynoka	1580	8,504	250,700	94,500	0	1903-05, 1937
	Canadian River at Bridgeport	2285	20,428	293,400	150,000	0	1944-69, 1969
	Beaver River near Guymon	2325	1,175	18,400	55,400	0	1937
	North Canadian River at Canton	2390	7,601	123,200	24,800	0	1937

FIGURE 3 LOCATIONS OF USGS STREAMFLOW GAGING STATIONS



Data—U.S. Geological Survey
Mapping—Oklahoma Water Resources Board

FIGURE 5 LOCATIONS OF USGS WATER QUALITY MONITORING STATIONS



Data—U.S. Geological Survey
Mapping—Oklahoma Water Resources Board

FIGURE 4 WATER QUALITY ANALYSES FOR SELECTED USGS MONITORING STATIONS

Station	Stream	Sulfate mg/L	Chloride mg/L	Nitrate Total mg/L	Solids, Residue at 180°	Hardness mg/L	Sodium	Specific Conductance Micromhos	pH
SOUTHEAST PLANNING REGION									
3325	Blue River near Blue								
	Mean	15 36	9.01	—	238.64	209.10	0.27	402.50	8 25
	Minimum	0.00	1.40	—	55.00	40 00	0.10	22 00	7.30
	Maximum	90 00	39.00	—	369 00	346.00	0.80	650.00	8 90
3340	Muddy Boggy Creek near Farris								
	Mean	14.08	20.36	—	131.83	61.87	0.89	212.99	7.24
	Minimum	0.00	2.50	—	29.00	8.00	0.10	39.00	3 20
	Maximum	161.00	139.00	—	513.00	219 00	7.00	1,140.00	8.60
3362	Kiamichi River near Big Cedar								
	Mean	13 26	10.24	—	70.00	28 24	0.80	71 69	7.33
	Minimum	0.00	1 00	—	70 00	12 00	0.80	28.00	6.20
	Maximum	44.00	42 00	—	70 00	88.00	0.80	125.00	8.70
3379	Glover River near Broken Bow								
	Mean	7.80	5.49	—	41.91	28.29	0.46	62.62	7.42
	Minimum	0.00	1.00	—	23.00	1.00	0 20	28.00	6.10
	Maximum	57.00	24.00	—	67.00	97.00	0.80	140.00	8.30
3390	Mountain Fork near Eagleton								
	Mean	4.65	3.65	—	38.36	14.25	0.49	48.57	7 25
	Minimum	0.00	0.80	—	15.00	6 00	0.10	26.00	6.10
	Maximum	51.00	18.00	—	68.00	27 00	1 00	750.00	8.30
CENTRAL PLANNING REGION									
2299	Lake Thunderbird near Norman								
	Mean	10.98	27.87	0.30	236.66	182.06	0 59	429.00	8.01
	Minimum	6 00	20.00	0.30	198 00	150.00	0 40	357.00	6.40
	Maximum	51 00	87.00	0.30	364 00	216.00	2.50	740.00	8.80
2395	North Canadian River near El Reno								
	Mean	188.96	134.79	—	621.10	320.35	2.20	1,134.03	8.00
	Minimum	13 00	6.60	—	120.00	80.00	0.40	187.00	7.00
	Maximum	1,013.00	394.00	—	1,210 00	727 00	4.10	2,200 00	9 40
2415.50	North Canadian River near Harrah								
	Mean	141.81	456.42	—	1,065.83	302.77	6 16	1,521.61	7.76
	Minimum	17.00	26.00	—	220.00	112 00	0.90	340.00	6.90
	Maximum	550 00	7,500.00	—	13,500 00	920 00	67 00	6,000.00	8.80
2423.50	Deep Fork near Arcadia								
	Mean	112.78	172 42	—	597.50	210 87	3 69	1,105 20	7.42
	Minimum	19 00	9 30	—	150.00	110 00	0 40	233.00	6.30
	Maximum	200.00	420.00	—	1,110.00	310 00	7.10	2,000.00	9 10
SOUTH CENTRAL PLANNING REGION									
3135	Beaver Creek near Waurika								
	Mean	168 71	101.16	—	641.94	370.55	1.53	980.49	8.04
	Minimum	7 80	4.50	—	115.00	58 00	0 20	153 00	6.50
	Maximum	400 00	450.00	—	1,360.00	680.00	6.10	2,080.00	8.70
3157	Mud Creek near Courtney								
	Mean	53.71	316.44	—	957 22	388.33	3.48	1,473.90	7.91
	Minimum	6 10	4 50	—	109.00	32 00	0.50	115 00	6.30
	Maximum	270 00	2,450.00	—	4,700.00	1,280.00	13.00	7,450.00	8.70
3159	Walnut Bayou near Burneyville								
	Mean	89 11	463.81	—	1,135.63	394.43	4.68	1,843.99	8.20
	Minimum	9.10	9 00	—	85.00	48.00	0.50	143.00	7.40
	Maximum	210.00	2,000.00	—	3,739.99	1,100.00	12.30	6,379.99	9.00
3285	Washita River near Pauls Valley								
	Mean	490.81	75.86	—	830.72	587 76	0.99	1,287.55	—
	Minimum	49 00	8.00	—	308.00	160 00	0 30	319.00	—
	Maximum	855 00	218.00	—	1,490.00	1,262.00	2 10	2,150.00	—

Station	Stream	Sulfate mg/L	Chloride mg/L	Nitrate Total mg/L	Solids, Residue at 180°	Hardness mg/L	Sodium	Specific Conductance Micromhos	pH
SOUTHWEST PLANNING REGION									
2284	Deer Creek at Hydro								
	Mean	488.74	17 17	—	914.82	607.91	0 55	1,173.32	7 93
	Minimum	58 00	0.30	—	203.00	140.00	0.00	290.00	7 00
	Maximum	1,060.00	38.00	—	1,660.00	1,060 00	3 40	1,890.00	8 50
3015	North Fork Red River near Carter								
	Mean	724.56	333 83	2.25	1,780.86	837.46	3.52	2,478.54	8.00
	Minimum	38.00	7.00	0.20	206 00	140.00	0.10	315.00	6.90
	Maximum	1,300.00	757.00	4.40	2,590.00	1,317 00	4.80	5,999.99	8.80
3030	North Fork Red River below Lake Altus near Lugert								
	Mean	575.65	999.20	—	1,300.00	902.28	2.75	4,893.86	8 12
	Minimum	405.00	196 00	—	1,200.00	200 00	2 60	1,290.00	7.40
	Maximum	773.00	5,328.99	—	1,420.00	1,964.00	2 90	17,999 96	8.40
3033.95	Elm Fork of North Fork Red River near Carl								
	Mean	1,684.44	2,906 01	—	7,480.91	2,051 67	14.08	9,987.46	7 73
	Minimum	510 00	46.00	—	1,130.00	630.00	0 40	1,360.00	7.00
	Maximum	3,499 99	49,999 91	—	87,199.81	7,699 98	149.00	103,999 75	8 90
3112	Blue Beaver Creek near Cache								
	Mean	16 68	7.63	0.20	106 27	52 37	0.75	190 52	7 43
	Minimum	7.20	3 40	0.10	58 00	26.00	0.50	89.00	6.40
	Maximum	90.00	24.00	0.40	187.00	81 00	1.40	2,500 00	8.60
3242	Washita River near Harmon								
	Mean	793.74	32.51	—	1,412 37	913 17	0.86	1,675 42	8 02
	Minimum	25 00	1.00	—	0.90	120 00	0 20	270.00	6.60
	Maximum	2,100.00	256 00	—	3,169 99	2,200 00	1 90	3,179 99	8 80
3244	Washita River near Foss								
	Mean	511 19	23 24	5 21	999.83	660 83	0 91	1,320 57	8.06
	Minimum	10.00	1.00	0 40	112.00	91 00	0.20	152 00	7 00
	Maximum	1,500.00	180.00	14.00	2,540.00	1,700.00	1 40	4,670 00	8.80
EAST CENTRAL PLANNING REGION									
1980	Illinois River near Gore								
	Mean	8.53	10.38	2.30	114.13	84.30	0.29	198.83	7.68
	Minimum	3 00	1.20	1.20	40.00	33 00	0.10	85.50	6 30
	Maximum	130.00	300.00	3.10	740 00	300.00	4.20	1,620.00	8 50
2310	Little River near Sasakwa								
	Mean	33.35	3,031.61	1 57	4,858 56	1,306 78	12 08	7,541.67	8 10
	Minimum	0.00	16.00	0.00	106 00	48 00	0.60	142 00	4 00
	Maximum	410.00	73,100 00	2.90	129,000 00	24,400 00	101 00	130,000 00	112.00
2420	North Canadian River near Wetumka								
	Mean	130.73	283 43	—	848.57	305 27	4.46	1,594 75	7.83
	Minimum	26.00	40.00	—	210.00	76 00	1.00	418.00	6 70
	Maximum	280 00	640.00	—	1,650.00	540 00	8 50	9,400 00	9 60
3357	Kiamichi River near Big Cedar								
	Mean	3.58	2 49	0 00	23 90	7 24	0.38	26 51	7.00
	Minimum	0.80	1 00	0 00	10.00	1 00	0 10	15.00	5.20
	Maximum	9.30	9.60	0.00	45.00	17 00	1 00	63 00	9.00
NORTHEAST PLANNING REGION									
1710	Verdigris River near Lenapah								
	Mean	39.57	96.45	0 15	387.77	196 09	2.02	646.83	7 92
	Minimum	5.60	7.00	0.15	114.00	48 00	0.40	124.00	6.40
	Maximum	150.00	375.00	0.15	937.00	370.00	5.60	1,560 00	9 50
1714	Verdigris River near Oologah								
	Mean	51.50	60.05	—	334.13	178 09	1 06	510.83	7 74
	Minimum	8.40	0.00	—	109 00	74.00	0.40	185.00	6 40
	Maximum	730 00	280.00	—	1,510.00	810.00	2 80	1,970.00	9.70

(Continued)

Station	Stream	Sulfate mg/L	Chloride mg/L	Nitrate Total mg/L	Solids, Residue at 180°	Hardness mg/L	Sodium	Specific Conductance Micromhos	pH
NORTHEAST PLANNING REGION (Continued)									
1755	Caney River near Ramona								
	Mean	31 95	118.75	—	401.85	193.28	1.72	686.18	7.97
	Minimum	2.10	8.30	—	76.00	41.00	0.30	127.00	3 00
	Maximum	112.00	610.00	—	1,380.00	490.00	5 70	5,170 00	9.90
1765	Bird Creek at Avant								
	Mean	21 27	52.82	—	233.30	140.75	0.98	413.71	7.94
	Minimum	1.00	1.00	—	68.00	28 00	0.60	112.00	7.10
	Maximum	49.00	116.00	—	340.00	212.00	1.50	700.00	12.40
1850	Neosho River near Commerce								
	Mean	76.33	25.87	—	306.10	20,323	0.80	476.88	7.88
	Minimum	12.00	1.00	—	102.00	51.00	0.10	130.00	6.20
	Maximum	238 00	158.00	—	690.00	535.00	2.90	1,080.00	9.00
1905	Neosho River near Langley								
	Mean	37.83	12.26	—	182.90	128.73	0.38	292.79	7.49
	Minimum	7.00	1.00	—	128.00	78.00	0.10	188.00	6.70
	Maximum	53.00	85.00	—	293.00	227.00	1.20	508 00	8.70
1935	Neosho River below Fort Gibson Lake near Fort Gibson								
	Mean	38.99	11.67	2.50	181.23	127.66	0.39	294 28	7.78
	Minimum	7.70	2.00	2.50	102 00	59.00	0.10	25.70	6.20
	Maximum	65.00	23.00	2.50	272.00	190.00	0.70	2,570.00	8 70
1945	Arkansas River near Muskogee								
	Mean	54.71	187.03	—	—	170.77	—	874.44	8.04
	Minimum	21.00	10.00	—	—	88.00	—	240 00	7.00
	Maximum	109.00	751.00	—	—	308.00	—	2,080.00	9.00
2435	Deep Fork near Beggs								
	Mean	77.19	158.21	—	537.03	216.13	3.15	936.09	7.88
	Minimum	13.00	37.00	—	148.00	47.00	1.00	250.00	7.00
	Maximum	170.00	270.00	—	865 00	340.00	5.30	1,750.00	9.00
NORTH CENTRAL PLANNING REGION									
1584	Salt Creek near Okeene								
	Mean	935.48	4,905.07	—	9,724.13	1,150.23	37.90	14,618.84	7.84
	Minimum	41 00	120.00	—	226.00	82 00	2.40	373.00	6.80
	Maximum	1,700.00	21,000.00	—	35,600.00	2,700.00	112.00	51,600.00	8 50
1591	Cimarron River near Dover								
	Mean	517.82	4,429.12	—	8,245.57	743.24	44.23	13,404 15	7.92
	Minimum	43.00	220.00	—	651.00	140 00	4.70	1,130 00	7.00
	Maximum	870.00	13,000.00	—	21,300.00	1,300.00	103.00	33,100 00	9.20
1597.5	Cottonwood Creek at Seward								
	Mean	157.86	107.81	—	636.50	312.31	2.37	1,077.14	7.72
	Minimum	9.10	16 00	—	49.00	55.00	0.70	127.00	6.70
	Maximum	290.00	200.00	—	1,030.00	550.00	4.60	9,000.00	9.30
1600	Cimarron River near Guthrie								
	Mean	498.93	3,043.28	—	4,880.58	715.54	27.15	9,685.48	8.09
	Minimum	70.00	190.00	—	611.00	86.00	4.80	1,080.00	6.80
	Maximum	1,020.00	7,178.99	—	11,300.00	1,238.00	63.00	18,799 96	8.70
NORTHWEST PLANNING REGION									
1484	Salt Fork Arkansas River near Alva								
	Mean	728.40	172.84	—	1,528.63	821.46	2.28	1,937.72	7.84
	Minimum	25.00	23.00	—	429.00	164.00	1.40	627.00	6.90
	Maximum	1,300.00	360.00	—	2,370.00	1,470 00	3.30	4,000.00	8 60
1505	Salt Fork Arkansas River near Jet								
	Mean	503.34	3,569.11	—	6,247.91	721.80	34.15	10,974.65	8.04
	Minimum	44.00	150.00	—	1,050.00	120 00	2.30	1,170.00	6.40
	Maximum	1,800.00	19,000.00	—	34,600.00	12,899.97	125.00	49,000 00	135.00

(Continued)

Station	Stream	Sulfate mg/L	Chloride mg/L	Nitrate Total mg/L	Solids, Residue at 180°	Hardness mg/L	Sodium	Specific Conductance Micromhos	pH
NORTHWEST PLANNING REGION (Continued)									
1579.5	Cimarron River near Buffalo								
	Mean	380 06	3,421.55	0 30	6,620 01	583.75	36.55	10,274.55	8 09
	Minimum	16 00	140.00	0.30	512.00	140 00	1.38	860 00	6.90
	Maximum	2,400.00	29,000.00	0.30	49,200 00	1,600 00	218 00	67,000.00	8 90
2285	Canadian River at Bridgeport								
	Mean	288.70	121.60	0.20	815.48	412.63	2.32	1,224 26	8.08
	Minimum	23.00	3.50	0.20	170 00	110 00	0.20	226 00	6.80
	Maximum	790 00	825.00	0.20	2,450 00	920 00	11 00	4,000 00	9 70
2375	North Canadian River at Woodward								
	Mean	343.96	309.17	—	1,316.94	516 94	4 39	1,990 52	8 32
	Minimum	75 00	100 00	—	400 00	172 00	2 10	693.00	7 30
	Maximum	930 00	600.00	—	3,110 00	970 00	8.30	3,539 99	9.40
2380	North Canadian River near Seiling								
	Mean	326 99	215.30	—	1,206.38	487.85	3.15	1,661.57	8 12
	Minimum	36.00	20.00	—	276 00	57 00	0.50	465 00	6 30
	Maximum	935 00	455.00	—	2,750.00	1,590 00	5 30	3,849.99	8.80
2390	North Canadian River at Canton								
	Mean	198.40	5,128 16	—	556 74	346 48	2 28	1,208 68	7 98
	Minimum	20.00	16.00	—	314.00	174.00	1.20	533 00	7 10
	Maximum	735.00	83,939.81	—	861 00	794 00	4 00	1,950 00	8 80

APPENDIX C
OKLAHOMA WATER RESOURCES MANAGEMENT STRUCTURE

FIGURE 6
STATE AGENCIES, BOARDS AND COMMISSIONS

WATER MANAGEMENT ACTIVITY

NAME OF AGENCY	PLANNING	REGULATION	DATA COLLECTION RESEARCH	ASSISTANCE	COORDINATION	DEVELOPMENT	WATER-RELATED RESPONSIBILITIES / DEFINITION
OKLAHOMA WATER RESOURCES BOARD	X	X	X	X	X	X	Prepares and updates the Oklahoma Comprehensive Water Plan. Administers the water laws of the state through the issuance of ground and stream water permits, makes ground and stream water investigations, promulgates and enforces water quality standards for the state; reviews and certifies Section 404 permits (P L. 92-500); issues waste disposal permits to industries, drafts and certifies National Pollutant Discharge Elimination System (NPDES) permits; certifies laboratories dealing with water resources; assists and improves organization of irrigation districts throughout the state Approves design and engineering of all nonfederal water works projects; compiles and indexes all available data concerning the water resources of the state; inspects water works projects to insure their safety, administers the Weather Modification Act; licenses water well drillers, coordinates the National Flood Insurance Program; negotiates and administers four interstate stream compacts. Administers a state financial assistance program for water development projects created by 82 O.S 1979, Section 1085.31, et. seq. (SB 215 of the First Session of the 37th Legislature).
DEPARTMENT OF HEALTH		X	X	X			Has responsibility for the prevention, control and abatement of water pollution associated with the discharge of municipal and other domestic waste and related public health and nuisance problems; has responsibility for the quality of public water supplies and public bathing places; administers EPA grants for construction of waste treatment facilities; has primary enforcement responsibilities under the Safe Drinking Water Act; develops and enforces standards for the disposal of solid wastes and controlled industrial waste, both surface (landfills) and underground
DEPARTMENT OF WILDLIFE CONSERVATION		X	X			X	Maintains certain pollution enforcement powers, is responsible for the investigation of fish kills and the assessment of damages to fish and wildlife from pollution; has responsibility for the construction and maintenance of 17 department lakes throughout the state.
OKLAHOMA CONSERVATION COMMISSION	X			X	X	X	Coordinates and provides technical assistance to the 88 conservation districts throughout the state for the establishment of best management practices concerning renewable natural resources through conservation and erosion control plans
ATTORNEY CENERAL		X					Aids in the interpretation and enforcement of water-related legislation and regulations affecting Oklahoma Water Resources Board. Approves all investment certificates issued by the Board to finance the loan program under SB 215.
UNIVERSITY OF OKLAHOMA							
Bureau of Water and Environmental Resources Research			X				State and federally funded department at the University of Oklahoma for water research and education programs.
Center for Economic and Management Research	X		X				Research arm of the College of Business Administration. Prime contracting agency with Oklahoma Water Resources Board to conduct a statewide economic impact study of the proposed water transfer system. Also under subcontract to perform the Energy Production Impact assessment for the State of Oklahoma in the High Plains Study.
National Severe Storms Laboratory			X		X		Investigates the application of weather radar to measure rainfall. Current and future efforts are directed toward the use of weather radar for streamflow and runoff studies.
State Climatologist	X		X				Responsible for the accumulation and dissemination of climatological data collected throughout the state and determines state policy regarding climate-related issues.

FIGURE 6
STATE AGENCIES, BOARDS AND COMMISSIONS (Continued)

WATER MANAGEMENT ACTIVITY

NAME OF AGENCY	PLANNING	REGULATION	DATA COLLECTION RESEARCH	ASSISTANCE	COORDINATION	DEVELOPMENT	WATER-RELATED RESPONSIBILITIES / DEFINITION
OKLAHOMA STATE UNIVERSITY							
College of Business Administration	X		X				Assists Oklahoma University in the statewide Economic Impact Study of the proposed water conveyance system in Oklahoma
Department of Agricultural Economics	X		X				Assists in the statewide Economic Impact Study and conducts the State Agricultural and Farm-Level Research Element of the High Plains Study
Agricultural Extension Service			X		X		Transfers experimental results and findings in economic and scientific agricultural research to the public. County agents at the field level advise laypersons of local irrigation conditions, trends and problems.
Water Resources Research Institute			X				Conducts scientific and political research studies on water-related problems and issues. Principal recipient of funding grants from the U S Office of Water Research and Technology
SUBSTATE PLANNING DISTRICTS	X		X	X	X		Regional public entities funded by the federal government through DECA to serve as the local coordinating agency encouraging social and economic development
DEPARTMENT OF CIVIL DEFENSE	X			X	X		Prepares, implements and coordinates disaster plans and operations related to droughts, floods, storms, etc
DEPARTMENT OF TRANSPORTATION	X		X	X	X	X	Has responsibility for the planning, construction, operation, maintenance and coordination of the state transportation systems. Participates in cooperative mapping program with OWRB and USGS. Coordinates with OWRB in the design of roads and bridges near potential dam sites.
TOURISM AND RECREATION DEPARTMENT	X					X	Promotes tourism and recreation through publicity and dissemination of information; develops, operates and maintains state parks, recreation areas and lodges. Has responsibility for the State Comprehensive Outdoor Recreation Plan (SCORP)
GRAND RIVER DAM AUTHORITY	X	X	X			X	Public corporation and agency of the State of Oklahoma created to control the water of the Grand River and its tributaries. Financed solely by revenues generated from the sale of water and power.
STATE DEPARTMENT OF AGRICULTURE		X	X				Has responsibilities in the areas of pesticide application, regulation and analysis, and in the control of water pollution from animal feed yards
CORPORATION COMMISSION		X					Makes and enforces rules governing and regulating pollution control related to the exploration, drilling, production and transportation of oil or gas products
SCHOOL LAND COMMISSION		X					Has responsibility for the effective management of state-owned land
DEPARTMENT OF MINES		X					Has responsibility for the enforcement of standards related to mining activities, including the reclamation of strip mining lands.
OFFICE OF THE GOVERNOR DEPARTMENT OF INDUSTRIAL DEVELOPMENT			X	X			Supports and assists efforts of industries to locate in Oklahoma. Assistance includes dissemination of information necessary for environmental decisionmaking.
POLLUTION CONTROL COORDINATING BOARD	X		X		X		Has responsibility for coordinating efforts of seven state agencies working in the field of environmental pollution: Oklahoma Water Resources Board, Oklahoma State Health Department; Oklahoma Conservation Commission; Corporation Commission; Industrial Development; Department of Wildlife Conservation, and Department of Agriculture
DEPARTMENT OF ECONOMIC AND COMMUNITY AFFAIRS				X	X		Administers federal funds for planning assistance to state agencies, substate planning districts and local communities.
EMPLOYMENT SECURITY COMMISSION	X		X		X		Compiles and publishes extensive data on the Oklahoma economy. Provides population forecasts for the state.
DEPARTMENT OF ENERGY			X	X			Coordinates, promotes and develops effective statewide energy programs.

WATER MANAGEMENT ACTIVITY

FIGURE 7
FEDERAL AGENCIES, BOARDS AND COMMISSIONS

NAME OF AGENCY	PLANNING	REGULATION	DATA COLLECTION RESEARCH	ASSISTANCE	COORDINATION	DEVELOPMENT	WATER-RELATED RESPONSIBILITIES / DEFINITION
DEPARTMENT OF AGRICULTURE							
Soil Conservation Service	X		X	X		X	Provides technical and financial assistance to state and local entities for small watershed projects. Administers Rural Development Act of 1972 which authorizes Resource Conservation and Development Districts.
Agricultural Research Service			X				Studies water needs with emphasis on agricultural research.
Agricultural Stabilization and Conservation Service				X			Administers federal cost-sharing program primarily for land treatment practices on individual farmlands.
Farmers Home Administration				X			Provides loans and grants to farmers and local entities of government for irrigation and drainage systems, watershed protection and flood prevention projects, community waste disposal systems and rural water supply systems, including rural communities up to 10,000 population.
WATER RESOURCES COUNCIL	X			X	X		Coordinates federal involvement in water resources activities; administers matching grants to states to help finance state water planning activities; promulgates principles and standards and procedures for planning federal water resource projects. Has primary responsbility for preparation of periodic National Water Assessment.
NUCLEAR REGULATORY COMMISSION		X					Has responsibility for overseeing nuclear activities on a national basis.
ENVIRONMENTAL PROTECTION AGENCY	X	X	X	X	X		Administers the National Environmental Protection Program which includes the planning and implementation of programs for clean water. Programs include: state grants for the development of integrated wastewater management programs; Section 106 wastewater management program; Section 208 area-wide planning grants for developing water quality improvement plans; grants to cities for waste treatment facilities; implementation of the Safe Drinking Water Act; implementation of the underground injection control program and the Toxic Substance Control Act; the Kerr Lab, located in Ada, Oklahoma, serves as a major ground water and pollution control laboratory and research station.
DEPARTMENT OF ENERGY							
Federal Energy Regulatory Commission		X		X			Provides technical assistance and review of water resource development projects in which hydroelectric power generation is among the project purposes.
Southwest Power Administration		X		X			Provides electrical power to Southwestern region.
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT				X			Makes grants and loans to local public agencies to finance water and sewer facilities under its community development block grant program
FEDERAL EMERGENCY MANAGEMENT AGENCY					X		Administers National Flood Insurance Act of 1968 which provides insurance protection in flood-prone areas and encourages states and communities to make land use adjustments to prevent unwise use of the floodplain. OWRB is the state coordinator of this program.
DEPARTMENT OF COMMERCE							
Census Bureau			X				Provides basic statistics about population and the nation's economy, including data necessary to water resources planning and development.
Small Business Administration				X			Provides disaster loan assistance.
Economic Development Administration				X			Provides financial assistance, technical planning, and research assistance for areas designated as redevelopment areas. Provides financial assistance in the form of public works and loans for water facilities to redevelop areas experiencing water shortages.
National Oceanic and Atmospheric Administration			X				Provides meteorological activities, hydrologic forecasts and climatological services through the National Weather Service.

FIGURE 7
FEDERAL AGENCIES, BOARDS AND COMMISSIONS (Continued)

WATER MANAGEMENT ACTIVITY

NAME OF AGENCY	PLANNING	REGULATION	DATA COLLECTION RESEARCH	ASSISTANCE	COORDINATION	DEVELOPMENT	WATER-RELATED RESPONSIBILITIES / DEFINITION
DEPARTMENT OF TRANSPORTATION		X					Has coast guard type function of "policing" reservoirs and navigable waters; provides funding to interstate highways system; and has concern for highway drainage and flooding problems.
DEPARTMENT OF INTERIOR							
Bureau of Reclamation	X		X	X		X	Has major responsiblities in irrigation and the planning and development of multipurpose water projects. Administers the Small Reclamation Projects Act of 1906, which provides loans and grants for water projects in which irrigation is a primary purpose.
Fish and Wildlife Service	X		X	X			Assists states in planning and develoment of projects for restoration and management of fish and wildlife resources.
U.S. Geological Survey			X	X			Maintains through cooperative agreements (matching funds) stream gaging stations throughout the state; conducts ground water investigations.
Bureau of Land Management			X	X			Distributes in lieu of tax payments to counties where the federal government has purchased lands for water projects; provides for the leasing of federally owned mineral deposits.
Bureau of Indian Affairs		X		X			Represents Indian water right interests.
National Park Service	X			X			Provides planning and technical assistance to recreation areas related to water projects and water-related portions of national parks.
Heritage Conservation and Recreation Service (Bureau of Outdoor Recreation)				X	X		Coordinates state and federal programs for outdoor recreation; assists in evaluation of areas for possible wild and scenic river status; participates in planning, coordination and establishment of uniform policies relating to recreation, fish and wildlife benefits and costs of federal multipurpose water resource projects.
Office of Water Research Technology			X	X			Supports water research through Water Resources Research Institute at universities. A primary involvement is in the area of technological advancement of desalting processes.
DEPARTMENT OF THE ARMY							
Corps of Engineers	X	X	X	X		X	Has major responsibilities in flood protection, navigation and the planning and development of multipurpose water projects; regulates the disposal of dredge and fill material in navigable waters (Section 404-P.L. 92-500). The OWRB assists the Corps in the review and certification process. Lead agency in the National Safety of Dams Program.

FIGURE 8
MULTISTATE ORGANIZATIONS

NAME OF AGENCY							WATER-RELATED RESPONSIBILITIES / DEFINITION
HIGH PLAINS STUDY COUNCIL	X				X		Administrative body composed of representatives of the Six High Plains States and the U.S. Dept. of Commerce (EDA). Organized to monitor and coordinate the $6 million study of the declining Ogallala ground water formation in the High Plains. The study will consider plans to increase water supplies in the area.
ARKANSAS RIVER COORDINATING COMMITTEE					X		Committee members include representatives from Oklahoma, Kansas, and Arkansas. Primarily an advisory group to the Corps of Engineers with respect to reservoir and navigation operation on the Arkansas River.
ARKANSAS-WHITE-RED BASIN INTER-AGENCY COMMITTEE	X		X		X		Interstate committee concerned with water development in the Arkansas, White and Red River basins. Primarily a regional planning body made up of eight states, plus six federal agencies.

FIGURE 8 MULTISTATE ORGANIZATIONS (Continued)

WATER MANAGEMENT ACTIVITY

NAME OF AGENCY	PLANNING	REGULATION	DATA COLLECTION RESEARCH	ASSISTANCE	COORDINATION	DEVELOPMENT	WATER-RELATED RESPONSIBILITIES / DEFINITION
ARKANSAS BASIN DEVELOPMENT ASSOCIATION					X		Organization involving the States of Arkansas, Colorado, Kansas, Oklahoma and Missouri to promote the development of the Arkansas River basin.
RED RIVER VALLEY ASSOCIATION					X		Organization involving the States of Oklahoma, Texas, Arkansas and Louisiana to promote the timely and orderly development of the land and water resources of the Red River Basin.
OZARKS REGIONAL COMMISSION				X			Provides grants to local entities for water development projects to assist in the economic development of the States of Kansas, Missouri, Arkansas and Oklahoma.
RIVER BASIN COMMISSIONS & INTERSTATE COMPACTS Arkansas River Compact-Okla & Ark Arkansas River Compact-Okla & Kan Canadian River Compact-Okla, Tex & N Mex Red River Compact-Okla, Tex, Ark & La	X	X			X		Commissions promote comity between participating states by cooperating in the equitable apportionment and development of the water in specific river basins as provided by the Interstate Compact agreements. Oklahoma's role is fulfilled administratively by OWRB.

FIGURE 9 LOCAL AND SPECIAL PURPOSE DISTRICTS

NAME OF AGENCY	PLANNING	REGULATION	DATA COLLECTION RESEARCH	ASSISTANCE	COORDINATION	DEVELOPMENT	WATER-RELATED RESPONSIBILITIES / DEFINITION
MASTER CONSERVANCY DISTRICTS			X		X		Created under Title 82 O.S 1971 §531 et seq. for the purposes of preventing floods, regulating streamflows, reclaiming wetlands, diverting water, and developing and providing water for beneficial purposes. There are eight master conservancy districts in the state.
IRRIGATION DISTRICTS					X		Two irrigation districts currently operate in the state, and three others have petitioned OWRB to organize.
WEATHER MODIFICATION DISTRICTS					X		Title 2 O.S. Supp. 1973, §1403 et seq. created these districts, allowing districts to hold elections and assess themselves for cost of contracting weather modification projects, with the contracts to be filed with and approved by OWRB. At this time, no such districts exist in Oklahoma.
RURAL WATER DISTRICTS					X	X	Created by Title 82 O.S. Supp. 1975 §1324 to provide for water distribution facilities in areas lying outside the corporate limits of any municipal corporation or, if the municipality has a population less than 10,000 persons, may include said municipality. There are over 400 districts statewide.
SCENIC RIVER COMMISSIONS		X				X	Created to ensure the state's scenic rivers are properly managed and their pristine environment is maintained.
PORT AUTHORITIES	X				X	X	Has responsibility for the development, operation and expansion of ports in Oklahoma. City of Tulsa-Rogers Co. Muskogee City-County Sallisaw
OTTAWA RECLAMATION AUTHORITY		X		X			Has responsibility for the reclamation of hazardous mining land within the district.

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